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INVERTEBRATE DISSECTIONS.

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INVERTEBRATE DISSECTIONS.

DESCRIBED DIRECTLY FROM SPECIMENS READILY OBTAINABLE, IN A
FORM SUITABLE FOR THE USE OF STUDENTS AS A
LABORATORY GUIDE IN A FIRST COURSE
IN GENERAL ZOOLOGY.

SECOND EDITION.—REVISED AND ENLARGED.

BY HENRY LESLIE OSBORN, PH. D.

Professor of Biology and Geology in Hamline University, St. Paul, Minn.

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PREFACE.

The first edition of this book was designed for use solely as a laboratory guide; it having been exhausted and a second edition being called for, it has seemed desirable to extend the plan so as to include some directions for reading and theoretical study as well as the purely laboratory directions. In order to accomplish both of these ends the tabular form of the first edition has been replaced by more continuous style, but so arranged as to direct the student in his search for the demonstrable anatomical facts. Facts of anatomy not readily demonstrable and some physiological points are given to fill out the descriptions; these are either given in additional fine-print paragraphs or are bracketed in the solid reading matter. The number of types described has been considerably added to, besides considerable direction for finding and preparing specimens; there are brief descriptions of forms less suitable for laboratory work. References to the more easily accessible literature of the subject are given with each class, and a synopsis of the leading morphological characters of the principal classes and orders is placed at the end and forms a key to the classification of the animal kingdom. Without ignoring the value to the advanced zoologist of the best modern methods of zoological technique, we consider that they only hamper the beginning student, and have therefor confined the work to such as can be done by anyone who is in earnest, using only the simpler tools and lower magnifying powers.

No student can expect to make any real progress in zoology unless he forms the inflexible habit of recording by means of drawings, accompanied with indexing and description, every fact which he determines. These drawings need not be masterpieces of pictorial art, but they should invariably be made as a definite part of the study. It is best to make them with a pen, using water-proof india ink; they should be dated and the scale shown, and all facts relating to the history of the specimen should be entered with it. Drawings should all be made on one side of the paper, not on both, and on sheets of uniform size for convenience of filing.

GENERAL WORKS OF REFERENCE: *Balfour*, Comparative Embryology; *Huxley*, Anatomy of Invertebrates; *Claus-Sedgwick*, Text-Book of Zoology; *Lang*, Text-Book of Comparative Anatomy; *Leunis*, Synopsis der Thier-Kunde; *McMurrich*, Invertebrate Morphology; *Packard*, Text-Book of Zoology; *Rolleston*, Forms of Animal Life.—Riverside Natural History.

CHAPTER I.—GENERAL NOTES ON METHODS.

FIELD STUDY. The wider and fuller out-of-door acquaintance with animals the student can bring to bear upon his study of zoology the better. The best plan is for him to inspect at all possible hours of the day (and night) and at all seasons of the year, at first, places easily accessible, then all sorts of situations to discover their native fauna; he must consider the timidity of animals with their alert senses and approach them cautiously and remain quiet long enough to give time for them to recover from fright. His observations should refer not solely to their modes of escape from harm, but also to the more normal and usual occupations, such as relate to their nutrition and reproduction. The situations in which to look for zoological materials can hardly be classified; search everywhere: the walls of buildings, piles of wood or lumber, on and under stones, in the grass, on the bark of trees, on leaves and on flower clusters, between the bark and the wood of partly dead trees or of cord-wood, in rotting wood e. g. stumps, in dry leaves and mould in forests; in running, still, deep and shallow water, on the under sides of stones in water, on posts driven in water to support wharves, in the sand and in mud on bottoms, on stems and leaves of aquatic plants; and for parisites in and on all animals. In a great many cases animals will be found after waiting, they have hidden on your approach, having seen you before you saw them; they will come out if you are still and do not keep them terrified.

COLLECTING. Modes of collecting the larger and more noticeable animals will suggest themselves; smaller insects in the grass can be gotten by drawing across it a bag made of white muslin cloth, supported on a strong wire frame (opening of about 18x9 inches); the contents will appear on the cotton and can be removed to alcohol or a poison bottle. Many aquatic animals will be obtained by spreading out, in a pan of water, some of the grass and water plants obtained from some pond or stream. The mud, too, of such a place will, after standing in water, settle to the bottom and its inhabitants will, after a few hours, resume their common activities. The clearer water of ponds and streams is often inhabited by minute swimming forms; these can be caught by the "tow-net," which is a gauze net too fine-meshed to allow any but the most microscopic animals to escape. Such a net should after towing it through the water be washed gently (inside out) in a vessel containing water, and the water subsequently examined in a glass dish on proper colored background, when the animals will be seen by their motions or form; they can then be caught with a pipette and transferred to a watch glass or slide for close examination. The slime on the surface of leaves in the water will often furnish interesting material for the microscopist, such as Protozoa, Rotifers, Naid and other worms, Planaria, etc.

KILLING. Larger animals can be killed either by dropping them directly into alcohol or corrosive sublimate solution (see page 9), or boiling water, or they can be exposed to the fumes of cyanide of potash in a "cyanide bottle," or of chloroform on cotton in the bottom of a bottle kept tightly closed. Careless or inexperienced persons should not be allowed to use cyanide poison, as it is very dangerous. The cyanide bottle is made by placing in the bottom of an wide-mouthed bottle a few pieces of cyanide of potash and covering this with a layer of fluid plaster of paris; the latter hardens and firmly holds the cyanide in place. Soft animals killed by the alcohol or corrosive method should be kept permanently in alcohol; this refers to mollusks, soft larvæ of insects, spiders, all vertebrates, all crustacea, etc.

PRESERVATION. The modes of preserving material are so various with different cases as to permit only a very general statement. All soft bodied animals must be preserved in alcohol; drying will shrink and alter them too much to leave them available for later study. The alcohol used should be at first weak (30 per cent.), and then gradually replaced by stronger till a strength of 80 per cent. is reached. The water extracted from the animal weakens the alcohol. Alcohol which has been used once can be saved and filtered and used as a first bath in subsequent cases, and over and over till it has entirely lost its strength. Alcohol which will not burn is not fit to use for any but perhaps a first bath. Insects and shells which have had their contents removed can be dried; the insects should be "pinned" on entomological pins and placed in special boxes which are dust and moth proof.

FIELD NOTES. All material collected in the field should be given a number, on a slip of paper kept with it, and an entry of a corresponding number should be made in a note book to show date, place and circumstances, including all facts which are not given by the specimen itself. The more minute the record of facts the better. Facts entrusted to the memory are always discounted when presented for acceptance in any doubtful cases.

LABORATORY WORK. A few general suggestions on this head will be helpful to persons who are working alone and are useful to all. The table should be as well lighted as possible, a seat by a window with the light falling directly on the dissection is desirable; of course, direct sun-light is too intense; never shade your work with your hand or with books or other objects; a posture not involving too much stooping is also desirable. All dissections are more satisfactory if performed in water (or alcohol), but the water must be changed as often as it is rendered turbid, either by running in fresh or by sending a stream of clear water on the object from a pipette. Where students are working in classes there should be as little dependence on each others work for suggestions as possible, the purpose being to find out how to ascertain facts for ourselves; we already know how to get them by asking for them of other people. A laboratory should be a place of absolute quiet, as quiet as a church. The waste material left from dissection should be thrown away in receptacles furnished for the purpose, and care should be taken that they are either buried, or better, if possible, burned; they should not be left where they can putrefy and fill the air with noxious vapors. The outfit needed for all the work given in the book is as follows: Scalpel, scissors, forceps, glass-rod, glass pipette, needles, probe, glass slides and cover glasses, cells, bibulous paper, alcohol lamp, hand-lens and stand (made by placing an upright post in a block of hard wood to carry the hand-lens), dissecting pan 1 inch deep, bottom covered with layer of paraffine thick enough to hold pins, (alcohol absolute,) alcohol 95 per cent., saturated aqueous solution of corrosive sublimate, hydrochloric acid, potassium hydrate (10 per cent.), glycerine jelly, oil of cloves, canada balsam, Borax Carmine, Higgins Water-Proof Drawing Ink; (a description of these articles and prices are given in the advertisement of Bausch & Lomb at the end of the book.) All tools entrusted to the student should be kept in good order, left dry and clean, and all supplies borrowed from the laboratory should after work be returned to their proper places. Reagents which have been taken from laboratory supply bottles should never be poured back into the bottle. After work your table should be left in complete order. Material on which work is still to be done can be left in alcohol and work on it resumed at a later date, if that is necessary.

CHAPTER II.—THE PHYLUM PROTOZOA.

While this Phylum does not strictly come within the limits proposed in the plan of this book, it is too important in numbers and morphologically to be passed without brief mention and reference. Outline descriptions of a few of the leading genera will hence be given, the student being referred to Professor E. Ray Lankester's article, "PROTOZOA," in the Encyclopædia Brittanica for fuller information.

1. **AMŒBA PROTEUS**,[*] lives in the scum on the surfaces of leaves of aquatic plants; it is perceptible only with a magnifying power of 300 diameters; its body is made of granular semi-fluid gelatinous material, *protoplasm;* there are two layers of the protoplasm, a clearer outer bounding thinner layer, *ectoplasm,* and the central mass which is more granular, *endoplasm,* and contains various objects more or less circular in form, these are *food* in process of digestion; besides these there are a central protoplasmic mass spherical in shape, *nucleus,* and a clear spherical object which at stated intervals contracts, *contractile vacuole.* Occasionally a line can be seen cutting across the body; it is an indication of the process of *fission,* a mode of *asexual* production. A study of Amœba will convince anyone that in spite of its minute size it is really an animal with all the functions which we call *vital,* though on so small a scale. The outline of the body is constantly varied by projections of the ectoplasm called *pseudopodia,* into which the endoplasm flows and the animal thus moves forward; food is encountered and accepted or rejected, implying *sensation;* if accepted the food is surrounded by the animal, *engulphing,* and is gradually *digested,* and later the indigestible parts are *rejected;* the food promotes *growth,* which, when the creature reaches a certain size, is followed by division of the body and *reproduction* results.

2. **DIFFLUGIA PYRIFORMIS** inhabits the same places as Amœba; it is covered with a shell composed of minute particles of stone which it has collected in the water; this shell takes the form of a vase, from the open end of which pseudopodia reach out and seek for food.

3. **PARAMÆCIUM** is a very active free organism, sometimes reaching a size which brings it near the range of objects barely perceptible to the naked eye It is found in water in which vegetable matter is slowly decaying; it is oval, covered with *cilia,* minute projections of the ectoplasm, endowed with the power of rapid motion and used as oars to row the animal through the water; on one side a depression leads into a *throat* at the bottom of which food is swallowed by engulphing as in Amœba. Contractile vacuole and nucleus are present, a transverse line indicating fission can occasionally be seen. In addition to this a mode called *conjugation,* in which two individuals meet and one completely absorbs the other, occasionally takes place.

4. **VORTICELLA** is found on the fine threads of filamentous water plants; it is mounted on a *contractile stem,* and is globular

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[*] See Leidy, Fresh-Water Rhizopods, U. S. Geol. Survey.

in form and carries a ring of cilia around the upper end, *peristome*, where also a *gullet* or passage leading into the body is located. At the bottom of this the food is engulphed. There are as before *contractile vacuole* and *nucleus*.

5. **ROTALIA** is a marine surface animal of microscopic size; it is a single *cell*, as are the rest of the Protozoa; has a nucleus surrounded by protoplasm, the body is surrounded by a shell made of *lime* which it has secreted, the shell is spiral in form and composed of a succession of ever enlarging chambers; long and fine threads of the ectoplasm are thrust out through the *pores* in the shell and they entangle food which is thus used to nourish the body.

As a group the Protozoa include a vast variety of forms, and they are of great interest as showing how much is possible in animal structure inside the limits of a single cell; they include parasitic as well as free organisms, and live thus in all situations except strictly terrestrial ones.

CHAPTER III.—THE PHYLUM COELENTERATA *(Hydroids, Polyps, Medusæ).*

PART I.—CL. HYDROZOA.

1. **HYDRA FUSCA** (*Brown-Hydra*).*

LIVING HYDRAS can often be found on the leaves of fresh-water plants by closely examining them in water, and are best for study, but alcoholic material can be used. The animal must be examined in water (or alcohol) with a hand-lens over a black back-ground. On a living animal, note the mobility of the body as a whole, also the independent mobility of the tentacles, the extended and contracted positions, its occasional creeping movements, its attraction toward light, the capture, killing and swallowing of prey, and draw views showing all these observations. This, or any small soft animals, can be preserved by first killing them in a saturated aqueous solution of corrosive sublimate—and then changing them to alcohol, at first weak, then stronger, till they finally arrive in 80 per cent. Metal tools must not touch corrosive sublimate.

THE BODY is simple but presents certain definite parts, viz.: the *base* by which it adheres; the *tentacles* in a ring around the end (*oral-end*) opposite the base; the *manubrium*, a conical area between the tentacles, in the centre of which the *mouth* is located; in some individuals a lump on the side, *bud*, develops into a new Hydra with tentacles, etc.; in rare instances buds have buds growing from them; in autumn small rounded lumps, *gonads*, are present, one near the tentacles, the *ovary*, and one nearer the base, the *spermary*. Illustrate all these points and index.

**Parker*, Elementary Biology.

[The DETAILED STRUCTURE of Hydra can be studied on a fresh specimen mounted in water, or a preserved one, in glycerine or canada balsam, under the low power compound microscope. The body is a hollow sack; its wall consists of two layers, an outer, *ectoderm*, and an inner, *endoderm;* each layer is continuous to the edge of the mouth, and through the whole length of the tentacles; the ectoderm (h. p.) consists of small cells, placed side by side, and on the tentacles, includes *nettle-cells*, often in lumpy groups; the endoderm consists of large cells used in the digestion of food; the ovary is located in the ectoderm and contains a single large cell, the *ovum*.]

All objects show better when they are mounted in some fluid medium; the simplest mounting fluid is water; the specimen in this case is placed in the centre of the slide (if thick surrounded by a cell), is surrounded by water and is covered with a glass cover. Glycerine is a better medium than water because it increases the translucency of the object; it is used in the same way. If it is desired to keep the object permanently, glycerine jelly can be used in place of glycerine; it is warmed and then used as ordinary glycerine, and forms a stiff jelly when cold. The best permanent medium is canada balsam, to use which the object must first be perfectly de-hydrated, or all its water removed by soaking in absolute or very strong alcohol, then soaked in oil of cloves till it is thoroughly translucent and then placed in the centre of the slide, the clove oil then removed with blotting paper as well as possible without injuring the specimen; then a drop of balsam is added and then the cover glass. A cell should be used in all cases where the object would be so thick as to leave the cover at all oblique if not used. The slide should be labeled to show date and treatment of the object.

2. **CLAVA** *sp.*

THE COLONY is marine and is found on sea-weed, as a cluster of similar polyps, *zooids*, connected at their bases by threads, *rhizoids*, which ramify over the surface of the sea-weed.

SINGLE ZOOIDS should be separated from the colony and mounted in glycerine; study them and determine and draw their shape; the location, number and shape of the tentacles; the location, number and shape of the globular structures, *medusa-buds*, among the tentacles. [Examine (l. p.) for double-layered body wall; and for nettle-cells.]

3. **TUBULARIA DIVISA** (*Tubularian Hydroid*).

This is a marine animal found in colonies attached to stones or submerged wood in the ocean near the surface. The colony consists of branching rhizoids, and tall vertical, slender stems, sometimes branching sparingly, bearing at their summits large multitentaculate zooids; there is only one kind of zooid in the colony. Draw.

A SINGLE ZOOID, detached with part of its stalk and examined in fluid in a watch glass, presents: on the stalk, a chitinous outer sheath, enclosing fleshy tissue (a hollow two-layered tube); the flesh is directly continuous with the base of the zooid; the chitine disappears at the base of the zooid; the naked body is pear-shaped, has a ring of tentacles about the upper end, *oral tentacles*, and a second circle of *basal tentacles*, and small stalks, each bearing numerous *medusa buds*. Cut the body open and note that it is hollow. [Mount a tentacle in glycerine and examine (h. p.) for two layers, a solid centre of square, nucleated endoderm cells, and on outer ectodermal layer containing nettle-cells.]

4. **PODOCORYNE** *sp.*

THE COLONY is *commensal*, living on the joints of the legs of the "Spider-Crab." It consists of the usual rhizoid portion, and of zooids unbranched and short-stemmed, of two kinds (*polymorphism*), viz.: *nutritive* or *feeding* zooids, longer, larger and with 15 oral tentacles and no medusa-buds, and reproductive zooids, *gonozooids*, with fewer tentacles, and clusters of medusa-buds near the summit of the body. Draw.

If LIVING COLONIES are kept in pure sea-water the medusa-buds will be found to detach themselves and become independent *medusæ*. They can best be studied (l. p.) alive on the stage of the microscope, but preserved specimens also show the anatomy. It is bell-shaped; hollow within, where the body, *manubrium*, hangs; the *mouth* is located at the free end of the manubrium, and is surrounded by oral *tentacles;* at its base the cavity of the manubrium opens into four *radial canals*, which run in the thickness of the bell to its margin and there open into a *circular canal* in the rim of the bell; there are hollow *marginal tentacles* located at certain definite points on the rim of the bell; at their bases there are masses of colored substance, *pigment spots*, supposed to be visual in function; a thin fold at the margin, the *veil*, partly closes the mouth of the bell; in the inside of the bell, on the radial canals, are located the *gonads*. (The eggs are thrown out into the water and fertilized there, and develop directly into larvæ, which attach themselves to the spider-crab, and, by budding, produce a new colony.)

5. **HYDRACTINIA ECHINATA.**

THE ANIMAL is marine and colonial, is attached to the surfaces of shells tenanted by Hermit-Crabs. The *colony* is *polymorphic*, consisting of: the *rhizoids*, bearing *feeding zooids* with circle of tentacles surrounding the terminal mouth; *protective zooids*, with swollen tip well supplied with nettle-cells, but no mouth; and *gonozooids*, carrying several sessile and undeveloped medusæ, which do not become free as in Podocoryne, but remain attached to the colony and throw off eggs to produce new colonies, or spermatozoa, according to their sex.

ZOOIDS of each kind should be detached and mounted in glycerine or balsam; this will render them translucent and it will be possible to gain an idea of their inner structure.

6. **OBELIA DICHOTOMA** (*Campanularian Hydroid*).

OBELIA is found in fuzzy masses growing on the surface of sea-weeds at the ocean surface near shore. Colonies grow also on stones and on the bodies of sedentary animals of many sorts. To see the zooids to good advantage the living colonies should be examined, since, in killing, the animal contracts so as to lose its normal form. Preserved material for examination should be stained with one of the carmines and mounted in glycerine or balsam.

THE COLONY as a whole presents: creeping rhizoids; numerous stalks rising from them, which are made up of joints, arranged end to end, and supported on minute *rings*, and, at regular intervals, giving rise to short side branches, the whole having a zig-zag appearance. The exact shape and arrangement of these parts should be determined and a drawing made.

[The best way to see the zooids and their relation to the chitinous skeleton is to stain and mount. STAINING with borax-carmine leaves the chitine yellow and the flesh red. Immerse specimen from alcohol in borax-carmine, leave it for half an hour, transfer it to alcohol to which 2 per cent. hydrochloric acid has been added, and wash out the carmine which has not combined with the protoplasm; then, either pass through absolute alcohol and oil of cloves into balsam, or mount direct in glycerine.]

A SINGLE STALK closely examined presents: a thin chitinous *external skeleton*, which is jointed; this can be divided into: the joints and rings, regularly arranged, and minute cups on the ends of the short side branches, *hydro-thecæ*, which contain the *nutritive zooids*, whose body and tentacles can (in favorable specimens) be seen. The chitinous skeleton encloses in all parts a stainable inner substance, the two-layered tubular *flesh* connecting the zooids. Besides the hydro-zooids which are enclosed in the hydrothecæ, there are occasional larger oval chitinous cases arising at the same joints as the hydro-zooids; these contain *gono-zooids*, a central fleshy stem, staining red, and rounded medusa-buds, which are set free and produce eggs through which new colonies are formed.

THE MEDUSÆ, (obtained by rearing a colony in sea-water,) differ from those of Podocoryne in important respects, viz.: they are not bell-shaped, but broad and flat; the tentacles are numerous and at regular intervals, not especially related to the radial canals; at the bases of some, in place of pigment spots, there are *otocysts*, small hollow vesicles, containing a highly refractive *otolyth;* these are often called "auditory organs," but are regarded as organs of the equilibrium sense, and not of hearing.

7. **SERTULARIA PUMILA** (*Sertularian Hydroid*).

This is a colonial marine form attached to sea-weed. It is not so dense as the colony of Obelia, but loosely branched, and the zooids are not stalked but are seated directly on the stem (*sessile*).

The SKELETON of Sertularia covers the flesh completely. After the form of the colony as a whole has been determined and drawn, a small representative part should be cut off and mounted in glycerine. The hand-lens (or low power) will show: a central stem, bearing at regular intervals, opposite narrow-mouthed cups, *hydro-thecæ*, which in life lodge the retracted hydro-zooids. In addition to the hydro-thecæ, there are occasional much larger sack-shaped *gono-thecæ*, attached to the main-stem at the same level with the hydro-thecæ; these, in life, contain a central fleshy stalk bearing medusa-buds which, never become free, but throw off eggs and then wither away. [The FEEDING POLYP of this colony is slender, and, like Obelia, has one circle of tentacles and bears no medusa-buds.]

These descriptions can be applied not only to the Hydroids for which they are drawn, but, with change to cover the differences of form, proportions, etc., to most of the common Hydroids of either the Atlantic or Pacific coasts. The differences that can be found are only of detail and not of fundamental body plan. The collector need not confuse some of the sea-weeds and the Polyzoa with this group, if a careful study of the anatomy be made.

BIBL.—*Allman*, Monogr. Gymnoblastic Hydroids, '71; *Agassiz*, Seaside Studies, '65; *Brooks*, Life Hist. of Hydro-Medusæ, '86; *Bunting*, Journ. Morphol, '94; *Fewkes*, Medusæ of Gulf-Stream, Ann. Rep. U. S. Fish Comm., '86; *Hincks*, British Hydroid Zoophytes, '68; *Huxley*, Oceanic Hydrozoa, '59; *Kleinenberg*, Hydra, '72; *Lankester*, Art. "Hydrozoa" Encyc. Britt., '90.

PART II.—CL. SCYPHOZOA.

1. **METRIDIUM MARGINATUM** (*Sea-Anemone, Polyp*).

Metridium is found attached to stones or timbers on the shores of the Atlantic ocean from New Jersey to Labrador. Very little idea of it can be had from dead alcoholic material. It should be seen alive to be appreciated. It can also be studied from prepared sections.

The LIVING SPECIMENS should be kept under observation in aquaria, where quiet treatment will encourage them to expand to their fullest extent; they will then display: a *body*, cylindrical in shape, attached by its *base* and bearing an opposite *oral* end, in the center of which is the *mouth*, and at the margin a large number of actively motile *tentacles*. The substance of the body is watery and translucent, allowing, if brightly illuminated, an indistinct view of the interior, which is better seen in sections to be divided by vertical walls, *septa*, into a large number of radial chambers, all opening into a central *stomach* cavity. A *throat* (lined with ectoderm) leads down from the mouth and opens into the stomach.

The living creature can be experimented on by gently touching the tentacles to note the withdrawal; and by roughly pinching the body when the oral end is drawn in and the animal takes a conical *contracted form*. Strong chemical reagents have the same effect, and this prevents their preservation expanded, except by most careful methods. Long white threads, *acontia*, covered with nettle-cells, are thrown out through the body wall during agitation.

In SECTIONS, which should be taken crosswise through the throat and also through the stomach levels, the student should observe: the single layer of *ectoderm* on the outside and lining the throat, the *supporting lamella* which is infolded at the septa, the double layer of endoderm on the septa and its single layer next the outer wall, the expanded *septal filaments* at the inner ends of the septa, and, if present, the *gonads* in the septæ. The number of septa should be counted and it should be determined whether there are a multiple of six. [It should be further noted that this polyp is one of the non-coral forming actinians, in contrast with Astrangia, which, while similar in soft-anatomy, does form a coral skeleton.]

2. ASTRANGIA DANÆ (*The Coral Polyp*).

This Actinian is found in the Atlantic ocean on shelly bottoms in shallow water, from Cape Cod to Florida. The animal to be studied at all satisfactorily must be studied alive.

THE COLONY as a whole is attached to a shell or stone and consists of round clusters of radial plates, above which the transparent flesh of the animal rises to a low conical *cral-disk* at the free end, in the center of which the elongate *mouth* is situated; a number of slender tentacles radiate from the oral-disk arising on its edge. A view of the colony should be drawn.

If the LIVING COLONY is kept quiet in sea-water the zooids will expands and present clear views of their parts. Each will be found to exhibit eighteen tentacles, and, on close inspection, the throat and mesenteric septa can be seen in the interior of the body. The internal structure must be determined by sections or by dissection of larger Actinians.

THE SKELETON, *coral*, shows, in the round areas, the location of the zooids; each of these presents a margin and in the centre radial plates of lime, in number a multiple of six; primary and secondary plates can be distinguished, in some cases the area is elongate and there are two radial systems of plates; these are the bases of polyps, which were in the act of dividing. The colony may be large and branched. Other corals of this order are comparable with this, with, however, in some cases, as the Brain-Corals, little direct similarity.

SCYPHO-MEDUSÆ live free in the surface of the ocean; they are discoidal in shape, quite large, commonly 6-12 inches in diameter; they have a central manubrium with tentacles, and the margin of the disk is tentacular; the germinal cells are formed in the endoderm, but escape by bursting through the walls of the underside of the disk. The larval form is a sort of hydra-stock from which disks are propagated by "strobilation," a sort of traverse fission. Accounts of them and bibliography are given in the Brittanica article, Hydrozoa of Lankester, who has assigned them to that class rather than to the Scyphozoa.

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CHAPTER IV.—THE PHYLUM PORIFERA *(Sponges).*

1. LEUCOSELENIA *(The Calcareous Sponge).*

The "sponge" of commerce is only the skeleton of sedentary, lowly-organized marine animals, belonging to a class of the "Horny Sponges" of much more complex organization than *Leucoselenia*. The flesh has been entirely removed by soaking in water, but the fibrous skeleton preserves the form of the original. Their organization becomes intelligible if we approach them through the calcareous sponges, of which several different kinds are found growing in salt water on stones, piles, sea-weeds, etc., at low tide level. Living specimens should be examined, and material preserved in alcohol after passing through a killing fluid, such as picric acid or corrosive sublimate. The colony should be studied entire in alcohol and the single zooids removed, stained and mounted in glycerine or balsam.

The COLONY presents: one or more main cylindrical or vase-shaped *stems*, connected below and all attached by a common *base*, and numerous smaller divisions, *buds*, growing from the main stem; in some instances these buds are forked; they have various positions and size. Draw the colony.

The ZOOID* is a thin walled hollow tube; its cavity, the *cloaca*, open at base to the rest of the colony, the summit of the body is directly open, the *osculum*, but guarded by a crown of sharp-pointed *spicules* of lime; in life a constant current of water flows out through the osculum, which is often called "excurrent orifice." The wall of the body is beset with tri-radiate lime *spicules*, imbedded in the flesh, but not connected to each other. The surface wall of the body is everywhere perforated by holes, *incurrent orifices*, placing the water outside in communication with that in the

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*See Ency. Britt. Art., Sponges, Fig. 1.

cloaca, and the holes are lined with flagellated cells whose action propells the water, thereby bringing food, which they capture and digest for the good of the body as a whole. The buds are similar to older zooids, but have no osculum.

Microscopic transverse sections show that the wall is composed of an inner cellular layer, *endoderm*, which also passes into the inhalent pores, and an outer nucleated layer, *ectoderm*, not distinctly cellular, between which two are spaces containing various kinds of cells, including the germinal cells. It is in this part that the spicules are formed.

2. EUSPONGIA OFFICINALIS (*Sheep-Sponge*).

The sponges of commerce are of this type, and they differ from Leucosolenia in the great complexity of their incurrent system, the wall of the typical vase being greatly increased in thickness. S. officinalis can be had at drug-stores. It lives on the coral reefs of Florida.

The BODY as a whole, in a perfect specimen, presents: a conical form, with broad *base*, and a summit where one or more *oscula* are located. Slice a dry specimen in two equal halves; you now can see the central *cloaca* (or there may be more than one communicating); in some places you will also be able to trace *incurrent passages* from the surface toward the cloaca. Draw, both the surface and the section.

Make a *thin section* of the horny skeleton, mount it in water and examine. Note: the very fine *chitinous fibres* seeming to run in all directions; study them closely and note that they all join so as to make a continuous network; there are two sets: one of *larger fibres*, which run somewhat parallel upward and outward from the base, and smaller fibres interlacing between the larger ones. Draw a view showing the arrangement of the fibres.

Compare other sponges with this, trying to find in them as many as possible of these parts.

There are several forms of fresh-water sponges. They grow on submerged wood; having the appearance of a green or brown crust on its surface. A close examination will disclose larger oscula and innumerable minute incurrent pores. The body wall does not assume the vase shape, but is broadly spread out on the surface of the wood. There are specules of silica in the wall, on whose form the determination of the systematic relations is in part based.

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CHAPTER V.—THE PHYLUM ECHINODERMA *(Star-Fish, Crinoids, Sea-Urchins, etc.).*

1. ASTERIAS FORBESII.

This *star-fish* lives on rocky or sandy bottoms on the shores of the Atlantic ocean and adjacent bays and sounds. It can often be found in tide-pools at low water. Live specimens should be observed to note their mode of locomotion and the use of the tube-feet. They can be killed by immersion in fresh-water then either preserved in alcohol or dried for the later study of the skeleton.

EXTERNALLY they present: a central *disk,* five radial *arms,* or *rays;* a deeply grooved *ventral* surface and an opposite *dorsal* surface; a *mouth,* located in the centre of the disk; a *madreporic plate,* located on the dorsal surface on the edge of the disk and at the meeting of two of the arms. The groove, *ambulacral, groove,* on the ventral surface of each ray, is bordered by a distinct row of spines [in the groove dried remains of the tube-feet may be visible]; the arms and disk are furnished with *spines;* these are arranged in a definite mid-dorsal row, and a couple of rows parallel with the border of the groove, elsewhere they are not definite in position; they are surrounded by a circle of minute *pedicellariæ;* these are snapping, jaw-like structures, barely visible with the hand-lens. Draw.

INTERNAL ANATOMY.* Take a preserved specimen of Asterias, carefully cut away the dorsal surface of one of its rays so as to display the organs within; in the same way remove the surfaces of two other rays; do this under water in a wax-bottomed pan. Notice: the *body-cavity,* or space containing the various organs, and that the body-wall is lined with a delicate skin, *mesentery,* which is reflected so as to support the organs. Carefully remove the dorsal surface of the disk, cutting around the madreporic plate so as not to injure it. Notice: the large soft masses running the entire length of the arm, *hepatic caeca;* they have a central *duct* and side chambers connected with the duct, and, at the central end, a single duct formed by the junction of the two ducts; this single *hepatic duct* should be traced till it enters a five-angled organ in the centre of the disk, the *pylorus.* Cut away the hepatic ducts and display the loose-walled *stomach* immediately under the pylorus; note that it bulges out into the bases of the rays, and at each of its angles is attached to two tapering slips of tissue, *retractor muscles,* which run along the middle of the ventral surface of the ray. Gently raise the under side of the stomach and note the constricted throat and mouth in the centre of the disk, and the membrane, *peristome,* which closes the ring of bone. (A tube, the rectum, is generally destroyed in

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*It is easier to open Asterias if you first dissolve the lime of the skeleton by soaking in 5 per cent. hydrochloric acid; this will not injure the flesh for dissection. For description see *Parker,* Elementary Biology.

opening the disk; dorsally, it opens to the exterior, *anus;* on this tube a branching organ, the *respiratory tree,* is located.) Draw, and then remove the alimentary organs.

The REPRODUCTIVE ORGANS are in pairs on the outer sides of the bases of the rays; their size varies with the breeding season; they consist of a central duct, which bears on all sides very numerous small spherical bodies looking like miniature bunches of grapes, which produce eggs or sperm cells; the sexes are separate; [their ducts open at the junction of the rays; the gonads can be removed, stained and mounted in glycerine, and their parts examined under the c. m.]

THE WATER-VASCULAR system, is a complex system, whose function is not very well understood. It consists of: a quadruple row of small bladders, *ampullæ,* in the floor of the ray, with tubular connection between the bones into the sucker-bearing *tube-feet* in the ambulacral groove; a *longitudinal water-vessel,* which connects the tube-feet, lies in the skin in the ambulacral groove (seen in cross-sections), and runs at its base into the circular water-vessel; [a *circular water-vessel,* which underlies the *oral-bones,* bounds the peristome;] the *vesicles* of *Poli,* five pairs of larger bladders at the bases of the rays, connected through the oral-bones with the circular water-vessel; a tubular duct, the *stone-canal,* lined with lime, extends from the circular water-vessel up to the *madreporic plate* at the base of one ray.

[CIRCULATORY and NERVOUS SYSTEMS are present in the skin in the under side of the ambulacral groove; they are best seen in microscopic sections of the groove, but cannot be readily demonstrated by ordinary dissection. Besides the retractor muscles of the stomach there are muscles in the skin which bend the arms stoutly].

THE SKELETON is composed of great numbers of short pieces of lime, jointed together in the skin, so as to combine strength with some degree of flexibility. If a ray be soaked in weak cold alkaline water over night the flesh will be partly dissolved and the bones be separable; they are definite in position. There are: a double row of *ambulacral* bones in the mid-ventral line of each ray; these are so placed as to leave a row of holes, through which the tube-feet pass out; they adjoin on their outer ends, and alternate with, a row of bones, which carry each two spines, and bound the ambulacral groove on each side; opposite about each three of these, a single bone reaches across to join cross-shaped bones, which form a distinct row, and each one of which bears a large spine. There is a second row of cross-shaped bones, parallel with the first, also bearing spines; then the side and dorsal surface of the ray is closed in with short bones, forming a general net-work, at their junction the remaining spines are carried, excepting a dorsal row carried on a mid-dorsal row of cross-shaped bones. In the disk the *madreporic plate* and *stone-canal* have been already mentioned; also the oral-bones, of which there are five pairs, each pierced with a hole for the passage of the vesicle of Poli. There is no difference between the skeleton of the disk on its dorsal side and that of the rays. The spines are attached to the bones of the arm by a sort of ball and socket joint. The minute "*minor pedicellariæ*" are clustered at the bases of the spines or scattered in the skin generally; they should be examined with a low power (x20) to show the two jaws, which, in life, keep up a constant snapping. Draw a view showing the arrangement of the bones of the skeleton.

THE DEVELOPMENT of the star-fish is very remarkable and can be readily followed by persons located at the sea-side. The eggs can be artificially fertilized and are among the most favorable objects for watching the segmentation, and the phenomena of maturation and fertilization. A larval form, which is bilateral, is produced, inside of which the radially symmetrical star-fish is produced. The larval stages are abundantly met in the "tow-net stuff." For details on this line various Embryological works must be consulted, such as Balfour's Comparative Embryology; help is given also in Brooks' Invertebrate Zoology.

OTHER STAR-FISH should be compared with Asterias, at least with regard to external anatomy, and comparative drawings should be made and indexed so as to draw attention to the comparisons. If material permits, dissection of the internal anatomy and of the skeleton should also be made.

2. **OPHIOPHOLIS BELLIS**, the *brittle-star*, is common on sea-weeds, on the shores of New England states; it creeps with a slow serpentine motion of its arms. The body is very distinctly divided into a *disk* and five *arms*, the arms being wholly distinct as to skeleton from the disk. There are distinct oral and aboral surfaces; there is no ambulacral groove on the oral surface of the arms. There is no distinct madreporic plate. The arm is covered with a series of plates, consisting of a *dorsal* and a *ventral plate*, and on each side, a *side plate*, bearing a definite number of spines. If the arm be softened the covering can be removed, displaying inside a row of *vertebral bones*, equal in number to the covering series; each one is composed of two equal halves, closely joined in the middle line. The *disk*, on the ventral side, presents a five-sided mouth opening; soak it and remove its dorsal skin; in the interior the vertebral bones are seen to cross into the disk and abut upon five pairs of *oral bones*, which meet inter-radially and bear *dental bones* at their junction, covered with small *teeth*.

3. **STRONGYLOCENTROTUS DROEBACHIENSIS**, the *sea-urchin*, is found in tide-pools and shallow water off the shores of New England and the middle states. It is flattened spherical in shape, more flattened on the *oral* side, and is covered with long,

slender, sharp *spines*. The body is covered with a *test* of immovably articulated pieces, which do not reach the centre of the oral surface, but leave there a space, the *peristome*, covered with a thin membrane. The centre of this membrane is occupied by five white pointed *teeth*. Remove the spines, noting that they are regularly radially arranged, and wash the test with warm, slightly alkaline, water, to clean off the remains of skin, and allow it to dry.

Beginning at the peristome, five *ambulacral rows*, each bearing double rows of minute pores, encircle the shell and meet at the apex of the dome. These rows alternate with five *inter-ambulacral rows*, not perforated, but bearing conspicuous *bosses*, for the articulation of spines. The aboral pole is encircled by a series of bones which have homologies widely among the Echinoderms. It consists of five larger *genital plates*, terminating the interambulacral rows, each is perforated by a large *genital opening*, and one, the larger, carries the *madreporic plate;* and there are also five small bones, *ocular plates*, alternating with the genitals and completing the ambulacral rows. Each is minutely perforated by the *ocular pore;* these plates are not symmetrically arranged around the center of the pole, their exact position should be determined and compared with that of allied forms (e. g., *Arbacia, Cidaris*). The Ambulacral rows and inter ambulacral rows are further made up of small bones, in pairs, which, in tests that have been soaked long enough to decay their ligaments, should be separated and their outlines and mode of articulation clearly determined. The articulations of the spines should be made out. The *Teeth* mentioned in the centre of the peristome are the outer ends of a complicated jaw. called by the fanciful name of *Aristotle's Lantern.*

4. **ECHINARACHNIUS PARMA**, the *sand-dollar*, is found on sandy bottoms near shore on the New England coast. Its form, at first, apparently unlike that of the sea-urchin, shows many points in common. There is a covering of minute *spines*, these when removed allow us to see a much flattend shell, greatly depressed from pole to pole, one surface *oral* is perforated by a central *peristome*, within which five *teeth* are visible, the *aboral surface* rises to the center, which is the aboral pole, around it are five leaf-shaped *petaloid areas* which, by inspection are proven to be five *ambulacral rows*, minute ocular pits are located at their summits; five *interambulacral rows* alternate with them, and terminate in four (not five) *genital pores*, the centre of the pole is occupied by the *madreporic plates*. The margin of the test is perforated by the opening for the *anus*, which is located in the middle of that interambulacral area from which the genital opening is wanting. The

oral surface is quite unlike the aboral, there are no ambulacral openings, there are, however, twenty rows of plates which are continuous with the aboral rows.

5. **PENTACTA FRONDOSA**, the *sea-cucumber*, is common on the coast of Maine, and farther north, on the rocks at low tide level. Unlike the star-fish and sea-urchins its body is not covered with shelly plates, but is *leathery;* it, however, has the same radial symmetry as the other echinoderms. Its form is globular as in the sea-urchin, but unlike them its polar diameter is greater, *prolate*, the animal thus rests on its sides and not on the ventral surface, as do the sea-urchins. The oral pole is at the anterior end; and the aboral, at the posterior end. The sides, however, do not differ and there is thus little bilateral symmetry in Pentacta. The oral end is furnished with branching *tentacles* in five sets of two each, one of the sets is rudimentery, making in all eight functional parts. The *tentacles* are situated upon a *pharynx* which, by the action of two sets of muscles, can be either *pro-tracted* or *retracted.* Five rows of *tube feet* pierce the body wall at equal intervals and run from the oral to the aboral pole, they mark the *ambulacral areas.* Underlying these areas inside the body cavity are the *radial water vessels*, the radial *nerves*, and strongly developed *radial muscles.*

INTERNALLY the anatomy in part resembles that of the echinoderms generally. There is a cartilaginous "*lantern*" through which the throat passes, the *alimentary tube* has no hepatic-cæca, it is longer than the body and is consequently folded; it is supported from the body wall by a *mesentery.* Near the anus there is an organ opening into it which runs forward, becoming much branched as it goes, it is called the *respiratory tree*; its walls are pulsatile; it is supposed to be a respiratory organ. A *circular water vessel* surrounds the throat, it has two large *Polian vesicles* attached to it, there is also attached to it a *stone canal* which, however, opens not to the exterior but to the body cavity. There are radial vessels and *ampullae* in the ambulacral areas, and *tube feet.* A *blood vascular* system is present, but unlike that of Asterias, it consists of a circular vessel from which branches are distributed to the respiratory tree. The nervous system is on the typical echinoderm plan. The *reproductive system* is located in the body cavity, it has a single terminal outlet at the bases of the tentacles; the branches of the gonads are interlaced with the divisions of the respiratory system; the sexes are separate. There is a larval form having the main features of the echinoderm type called an *auricularia.*

[Some of the sea cucumbers are much more bilateral than Pentacta. *Cuvieria* has one surface distinctly modified as a *foot* on which it moves while the rest is covered with overlapping, bony plates. it has thus a strong, superficial resemblance to the " worms " and is only shown to be an echinoderm by deeper study. It is interesting to note the very different ways in which the sea-urchins and sea-cucumbers have been modified from radial in the direction of bilateral symmetry, though without reaching it; in the former the depressed body has specialized the margins of the oblately flattened sphere as in the sand-dollar, and more deeply still in the Spatangoids, one part of the margin thus becoming the anterior end, towards which the mouth is attracted from the centre of the ventral surface; while in the sea-cucumber, the animal lies on its side and is thus elongate in its polar diameter, and then the sides are differentiated as dorsal and ventral.]

CRINOIDS are chiefly important as fossils, in some inland regions remains of their skeletons are found in the rocks. The animals, some of which are still living chiefly in the depths of the sea, are on the "brachiate" plan of Echinoderm structure; the arms, five in number, are branched at the margin of the disk and rebranched so as to be loosely, many-divided peripherally; the disk is attached in the centre of its aboral portion to a stem [made up of a series of stony pieces, *joints*], sometimes of a length of several feet, various strata (particularly palæozoic) contain pieces of the stem and more rarely remains of the disk or arms of crinoids.

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CHAPTER VI.—THE PHYLUM SCOLECIDA.

1. **PLANARIA TORVA**, one of the flat worms, is found in fresh-water, moving over the surface of submerged objects; it is often found on leaves, etc., in water, by searching their surface closely with a hand-lens. It is elongate, half an inch long, broad anteriorly, in which direction it moves with a steady progression, and is pointed posteriorly; it is dark brown in color; in the middle of the anterior end there are two black *eyes;* the *mouth* is located in the centre of the ventral surface, and there is no separate anus. The *alimentary system* consists of branching tubes, which pass into all parts from the mouth as a centre; some indications of these can be seen by viewing the animal as a transparent object. The body is covered with *cilia*, used in locomotion, of which indications can be seen in a specimen mounted alive. The structure can best be studied by reconstruction from serial sections.

2. **O. CESTODA**, the tape worms, can be sometimes had by searching through the intestine of cats or other carnivora. Only the most superficial facts can be made out by the beginner, the study of sections being absolutely necessary, as a method in this group. The body (if entire) consists of an anterior "head," which is enlarged in front, on whose summit there is placed a ring of

chitinous *hooks* and four *suckers*. There is no mouth on this "head," and there is no alimentary system present in any part of the animal. Behind the head, the body is divided, by transverse divisions, into a large number of separate and distinct *proglottids*. These are all of them alike, and consist chiefly of an elaborate hermaphrodite genital system, whose opening is located on the side of the proglottid. Each proglottid is thus a sexually perfect animal, and, if detached from the chain, is still capable of reproduction. The proglottids are developed by a process of *stobilation* in the area just behind the head.

3. **O. NEMATODA**, the thread worms, are represented by the vinegar-eel, Anguillula aceti. It is obtainable by diluting a few drops of the "mother of vinegar" with pure water, when the "eels" can be barely seen with the hand-lens. The specimen must be mounted and studied with the compound microscope. Its cross-section is thus seen to be round, not flat; it has a blunter anterior and a sharper posterior end. Its movements are produced by means of muscles, its body being cuticular and non-ciliated. The alimentary system is a continuous tube, with mouth and anus, and is distinctly divided into regions, viz.: a throat, a muscular *gizzard* and a glandular portion. There is a nervous system, but there are no organs of special sense. Reproduction is solely sexual and the sexes are separate; the eggs in various stages of development can often be clearly seen in the genital duct of the female.

C. ROTIFERA is made up of microscopic animals, of various forms; their leading trait is the possession of two ciliated lobes, which are located on each side of the mouth at the anterior end of the body, and they generally have at the opposite end a sort of tail made up of two pieces, which appose each other and serve as a grasping organ. Their organization is very complex in spite of their minute size, and includes alimentary, excretory, respiratory, muscular, nervous and sexual reproductive systems. The body is sometimes jointed externally, but, if so, there is no internal segmentation like that of the true segmented worms (see Annelida).

The Phylum Scolecida includes a large number of parasitic animals, many of them closely related to man, and hence of great importance; but they are not adapted to elementary work in the laboratory, and their mention here has therefore been very meagre. The subject can be looked up from the following bibliographical list, if desired.

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CHAPTER VII.—THE PHYLUM MOLLUSCOIDA.

The name which has been given to the animals here associated is unfortunate because it implies an unproved relation of the group with the true Mollusk, but their assignment to the "worms" seems equally injudicious; their mutual relation, in spite of their very diverse outward form is generally accepted. The Phylum is chiefly a marine one, the brachiopods are wholly so, but fossil remains of both groups are so common in the Central states that a recognition of them is desirable.

The POLYZOA (well treated in the Brittanica by E. R. Lankester, to which reference can be made for particulars) are small but complex animals, always living in colonies; the zooids occupy small chambers into which they retreat on alarm; in fresh water they are found attached to stones and submerged sticks; if the colony be kept alive and quiet the zooids will be tempted out and their horse-shoe shaped arms with long and graceful tentacles will be visible under a hand lens. The mode of association of the zooids is various and gives rise to several different kinds of skeletal growths; one of these is represented in fresh water, it is a loosely branched "mossy" chitinous mass, somewhat resembling the hydroids; on the main stems are located the *cells* or coverings for the zooids. In other kinds the zooids secrete lime in the form of a scaly *incrustation* with the cells close together, and dotted with the *openings* of the cells, which are visible with a hand lens or barely with the naked eye. Colonies of this kind as well as the next are often found fossil in the *palæozoic* strata. The third form of skeleton is a branching coral-like calcareous structure whose surface is marked at close intervals with minute holes, the openings of the cells.

The Class BRACHIOPODA (see E. Britt. Art. Brachiopoda) is entirely marine, and though of great importance in early geological times is now nearly extinct. Their remains are met frequently in the central states as fossils. Though externally unlike the polyzoa, being solitary and not colonial, and comparatively large, they are internally like them in many structural points.

They are covered with a *bivalve* calcareous shell, which is often confused with the shell of true mollusks, but from which it differs radically. The brachiopod shell is always bilaterally symmetrical, that is its *two sides* are alike, as rights and lefts, and the two valves are different and dosal or ventral to the animal. The molluscan shell on the other hand is not bilaterally symmetrical, but *the two valves* are alike, as rights and lefts. The remains of both these classes can be found as fossils in many localities and the external facts easily demonstrated.

CHAPTER VIII.—THE PHYLUM MOLLUSCA *(Shell-Fish).*

PART I.—CLASS LAMELLIBRANCHIA *(Mussels, Clams)*

UNIO* *sp.* (*Clam, Fresh-Water Mussel*).

The HOME of *Unio*, and its close ally, *Anodonta*, is in rivers and lakes, where it can be found by closely inspecting the bottom. The animal lies buried in the sand, all except the posterior end of the shell, which in color imitates an oval, greenish black stone. A living specimen should be placed in a tumbler surrounded with sand in a "natural" position. After a short time of quiet the two shells will yawn apart disclosing two holes, *Siphons*, surrounded with greenish *tentacles*, a constant current passes in at one of the holes, *incurrent*, and another out at the other, *excurrent*, a third hole can also be seen. If the tentacles be touched gently, the sipons will be withdrawn and the shells closed; the action will be violent and "squirt" out a jet of water, if the disturbance is forcible.

1. THE SHELL. Study a dried shell of Unio. It entirely encloses the fleshy parts; it is composed of two similar *valves;* the convex outer surface, greenish in color from the *epidermis*, a thin chitinous layer, presents: concentric *lines* of *growth*, which center around a rounded *umbo;* the umbo is not located in the centre of the valve, but nearer the *anterior* and nearer the *dorsal* border; the two valves are connected by means of a transverse *hinge-ligament* composed of chitinous substance (a modification of the epidermis) and (in Unio) held by certain *hinge teeth*, which fit closely together. The concave inside surface of the shell is lined with a pearly layer, *nacre*, this is shiny in general but dull at certain places where the tissues of the animal were firmly attached to the shell, these places called *impressions*, are as follows: an *anterior* and *posterior adductor impression*, large and rounded in either end of the valve; a *pallial line* running parallel with the ventral border of the valve and from one to the other adductor impression; two *pedal impressions* closely related to the adductor impressions or forming part of them. (Other Lamellibranch shells should be compared with this and drawings made of all).

**Huxley* and *Martin*, Practical Biology; *Parker*, El. Biology.

2. EXTERNAL ANATOMY. Specimens can be killed by immersion in boiling water till the valves open; they can then be dissected at once or preserved in alcohol for work when convenient. Carefully remove the animal from its shell, noting all points of attachment; immerse under water, and note all the parts which can be seen without cutting. The two adductor muscles are not covered by the mantle; the mantle encloses the body and lies next the shell (which it secreted); its ventral part is free from the body and walls in a space, the *mantle chamber;* its margin is black and minutely fringed; at the posterior end the fringe becomes a mass of longer tentacles surrounding the *branchial siphon.** Folding back the mantle discloses within its chamber a number of different organs. Outermost are the gills, two long flat plates, filamentous in structure, free ventrally and attached above, and running from the posterior border of the mantle forward to near the anterior end.† At their anterior end on each side there are a pair of *labial palpi,* thin folds of a rounded form, somewhat similar in texture to the gills. In the middle line and anterior in position is the foot; it is tough and firm on the margin, but softer above, where it passes into the visceral mass. The mouth lies between the anterior end of the foot and the anterior adductor muscle; it is broad and narrow, and bounded on the ends by the labial palpi. The gills meet dorsally to form the floor of the *cloacal chamber,* the excurrent siphon opens out from it to the exterior, the *posterior adductor muscle* passes directly through it. Dorsally, and in front, the end of the *pedal muscle* can be seen beside the anterior adductor muscle, and more dorsally, in the space lying in the umbonal region of the shell, is the soft *visceral mass.* On the dorsal side, under the hinge-ligament between the visceral mass and the cloacal chamber, lies the thin-walled *pericardial chamber.* These points must be drawn and clearly fixed in mind before the succeeding descriptions can be clearly followed.

3. INTERNAL ANATOMY. Remove the side wall of the pericardial chamber, displaying the organs within; the space is traversed from end to end by the *intestine,* which runs from the visceral mass, out at the posterior side of the chamber, and passes above the post-adductor muscle, where it ends in the dorsal portion of the cloacal chamber, in the *anus.* The intestine is surrounded in the centre of the chamber by the *ventricle* of the heart, into which, on either side, a thin-walled pyramidal organ, the *auricle,* passes. This can be traced at one end to the bases of the gills; by cutting

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*The edges of the mantle are united, posteriorly, in some Lammellibranchs, e. g. Mya, and prolonged to form elongate siphons.

†In the breeding season the hinder half of the outer gill of Unio, and all the outer gill of Anodon, is greatly swollen, being filled with eggs and serving as a brood-chamber.

open, at its entrance to the ventricle, *valves* can be seen, placed so as to direct a current from the auricles into the ventricles. No distinct blood-vessels are seen. Beneath and behind the pericardial chamber a certain amount of dark greenish brown tissue is placed; it forms part of the wall of a tubular organ, the Organ of *Bojanus* (*nephridium, kidney*). [The tube is bent upon itself, running from an opening at the front end of the pericardial chamber—which equals the body cavity of Arthropods and Vertebrates—back and forward again to open into a prolongation of the cloacal chamber lying between the pericardial chamber and the bases of the gills.]

With a sharp scalpel divide the foot and viscera into two equal halves, to study the ALIMENTARY TUBE. Notice: the *mouth*, destitute of masticatory organs; the enlarged *stomach*, its walls surrounded with greenish liver-tissue, or *pancreas;* the *intestine*, imbedded in the connective tissue and muscle of the visceral mass; it makes several windings, which can be followed by careful dissection, of both sides, and will be found to emerge at the anterior boundary of the pericardial chamber. The cut will show that the ventral portion of the foot is wholly composed of *muscular tissue*, in the form of close tough fibres; the sides of the visceral mass are also muscular; the muscles of the foot continue both forward and backward, as the *pedal muscles*, and are attached to the shell. The margins of the mantle are also muscular, as well as the tentacles, and the great adductors of the shell belong to the muscular system.

The NERVOUS SYSTEM consists of three main *ganglia* and their connecting nerves, *commissures;* and of the nerves from them to the sense-organs and other parts. The two *cerebral ganglia*, separated by the diameter of the mouth, lie at the bases of the labial palpi, and are connected by a commissure running in front of the mouth, beneath the anterior adductor muscle. They are connected both to the pedal and the visceral ganglia. The *visceral ganglia* are distinct, but closely connected in the middle line; they lie directly under the post-adductor muscle and are stellate in form. Nerves can, in favorable cases, be traced from them to the hinder margin of the mantle; a nerve can also be traced from each half forward, passing in the side wall of the body to either cerebral ganglion. The *pedal ganglia* are also in two closely associated parts; they lie in the foot in the anterior and ventral angle, and on the border of the tougher muscular part. Besides having nerves to the neighboring parts, it has two *commissures*, one to each cerebral ganglion. *Otocysts*, very small sacks containing minute crystalline *otolyths*, are connected with the pedal ganglia, one on the outside of each half, and are supposed to be equilibrium organs.

The GONADS occupy the hinder part of the visceral mass; they cannot be distinguished with the unpracticed eye from the connective tissue which surrounds the windings of the intestine; they open by an outlet near that of the nephridium into the anterior prolonged part of the cloacal chamber. The *sexes* are separate. The *eggs* develop in the gill, where they can be easily found in various stages of development; they develop into a bivalve larval form, *Glochidium*, which becomes for a time parasitic on the gills of fishes, and later establishes itself in the sand like its parent.

DETAILED STUDY of the *gills* should be made. They are each *double*, the outer folded back on itself outwardly, the inner reflected inwardly, and the space between these folds is directly in communication with the cloacal chamber; each *lamella* or plate of the gill can be separated into long strips, *filaments*, which cross it from the base to the tip, they are originally separate, long tentacle-like structures covered with cilia, but in the mature animal are grown together side by side to form a continuous plate; mount and study (l. p.) a single filaments of living gill and the *cilia* in action will be visible.

Specimens which have been hardened in alcohol should be cut into a series of thick *transverse sections* the exact location of each section being accurately maintained, the sections should then be examined in succession from end to end of the series, and the various organs located in each by comparison with the dissections made from the side. The examination of the sections can be conveniently made by placing them in the bottom of a shallow dish under water (or alcohol). Drawings of the sections through the post adductor muscle, behind the heart, through the heart at the entrance of the auricles and through the visceral mass should be carfully made,

COMPARISONS should be made of the structure of Unio with both the soft and hard clams and the oyster, and if possible other forms. These are marine animals but are common in many parts of the country, in the markets, and can generally be ordered, if not kept " in stock," through the fish dealers. They ought to be studied in the shell. Interesting differences will come out at once, as for instance, in the soft clam, *Mya*, the strong development of the siphons into long tubes, and in the oyster the entire absence of the anterior adductor muscle and other modifications of the Unio type of structure.

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PART II.—CL. GASTEROPODA.

LYMNÆUS APPRESSA (*Pond-Snail*).

While this description is drawn from the genus named, it can be used for almost any member of the class (with the exceptions noted). Snails contract so much in killing that it is necessary to study living specimens to get any idea of the form of the animal, and relation to the shell. There are plenty of different kinds found in fresh-water, besides the true land-snails, from any of which studies can be made.

1. LIVING SNAIL. Watch a live and active specimen and determine the following points: the *foot* is a soft, flattened division of the body, on which the creature moves, broader in front and tapering behind, very thin and mobile, and sensitive on the edges; the

head rests on the anterior part of the foot and is raised above it, and bears on each side a retractile *tentacle*, at the base of which and in front of it is an *eye;* in the middle line in front there is an opening, the *mouth*, from which from time to time an organ, the *radula*, is partially thrust out; the *visceral mass* continues the head region posteriorly and disappears in the windings of the spiral shell. The shell next the visceral mass is lined by a soft black tissue, the *mantle*, in which on the right side, at intervals, a hole, the *pneumopore*, opens and closes to pass air from the *lung* (a modified branchial cavity open in marine snails).

Keep a live snail under observation for some time, in a tumbler, and note its actions: those of locomotion, their rate, and the peculiar use of the foot, their movement on the surface of the water; those of sensation, with the edges of the foot as well as with the tentacles; the action of respiration, and of the radula in feeding. Note the slow and inert nature of the animal as compared with the agility of many other higher animal groups. In the spring,water-snails which are kept confined in glass vessels will deposit (in the night) gelatinous lumps, imbedded in which oval minute eggs are enclosed. The egg changes can be followed, and after a few days interesting larvæ are visible and their daily changes can be followed with the low-power.*

2. The SHELL, is thin and light, in the *Order Pulmonata*, to which Lymnæus belongs, and is composed mainly of chitinous material (in the marine snails it is more largely calcareous, and hence heavier); it is a spiral tapering tube, wound around a central axis, *columella;* its summit is the *spire*, its turns, the *whorls;* its open end is called the *mouth*, whose margins are, *inner lip* on the side of the axis and *outer lip* opposite. The mouth is on the right side of the axis, in most shells; in the few, where it is not (e. g. Physa), the shell is said to be "sinistral." [Shells of Gasteropods differ much, but on the lines of this description, and can all, with a few apparent exceptions, be reduced to this same type. As many of them as possible should be compared and their relations thus determined.]

3. INTERNAL ANATOMY. Pin the specimen, foot down, through the front end of the head and hind end of the foot. Beginning close behind the head, note and then cut away the *mantle wall*, folding it across on the left side, and noting the mantle chamber, and on its left and hinder wall the loose skin, the *lung*. (In Prosobranchs the mantle chamber is broadly open in front, and its hinder and left wall is occupied by a distinct gill.) Make a second cut from the head back to the visceral region, in the mid-dorsal line; draw the skin aside and

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*For details see *Brooks*, Biol. Studies J. H. Univ. IV, p. 73. 1878.

fasten it there. This will disclose a number of white threads, the *vas deferens*, beneath which are visible a number of important cephalic and visceral organs. The broader *pharynx* narrows to a slender *gullet*, which traverses the anterior region and runs back into the visceral mass, passing underneath a part of the genital system in its course, and opening into a spherical hard-walled *gizzard;* behind this a slender tube *intestine*, invested by the substance of the brown and spirally twisted *liver*, runs to the apex of the spire and then back, and passes out in the wall of the body on the right side to open in the *anus*, a short distance behind the right tentacle. The *central nerve ganglia* are, in Lymnæus, grouped close together, and surround the gullet just behind the pharynx; (in marine snails they are widely separated.) Three chief centres are recognizable: the *cephalic*, in front, and dorsal; the *pedal*, below, and connected by a collar; and the *visceral*, above and behind. Behind the nerve masses are two whitish *salivary glands*, from each of which a thread, the *duct*, can be traced forward; it opens into the pharynx. At the posterior left side of the mantle, near its junction with the body wall, there is a small cavity, *pericardium*, within which lies the *heart;* it consists of two parts: a thinner-walled *auricle* next to the lung (and thus in front of) a thicker-walled *ventricle.* Lying close against the ventricle, but not in the pericardial cavity, there is a solid rounded organ, the *kidney*, a duct from which can be traced to an opening close to the anus. The *reproductive organs* in Lymnæus are very complex; they consist of an *hermaphrodite gland*, at the base of the visceral mass beside the liver, but easily distinguished from it by its different texture, and a divided passage, one part of which, the *oviduct*, accompanies the duct from the liver, and the other part, the male portion, *sperm duct*, leads out by a long and greatly convoluted passage, ending in a *penis* in the right wall of the body, between the anus and the base of the right tentacle. If the pharynx be opened it will be possible to find in its floor a long brown-colored thread; this is the *radula* (odontophore, lingual ribbon); the compound microscope will show its innumerable minute *teeth*, used in rasping vegetable substance for food.

LIMAX *sp.* (*The Slug*).

LIMAX is nocturnal and hides during the daytime in dark, damp places; it is commonly found under boards, stones or dense masses of leaves. Living specimens, if obtainable, should be placed in a covered tumbler and watched, and their mode of locomotion, the use of the pneumopore, the action of the tentacles, as well as the form of the body, determined.

The BODY is worm-shaped but unsegmented; two surfaces are clearly distinguished: a rounded *dorsal* surface and a flat colorless *ventral* surface; the *anterior* end is blunt and bears a pair of *ten-*

tacles, and the *mouth;* the posterior end is tapering; the *tentacles*, two in number, are hollow and can be wholly retraced by inversion; the *eye* is located at their tip; on the dorsal surface, behind the head and more to the right side, an oval area represents externally the aborted *mantle*, as in *Lymnæus;* it is grown to the body wall except at one point, the *pneumopore;* concentric markings on its surface overlie a small, internal, chitinous shell, which is the homologue of the shell of other snails. The hinder dorsal region is occupied by the various viscera.

The inner structure of Limax is closely similar to that of Lymnæus; it can be examined by pinning the animal down under water and opening in the mid-dorsal line.

Drawings of the living animal in several positions should be made; also, at least one drawing of the dissection, to show the location and shape of the organs.

BIBL.—*Binney*, Bull. U. S. Nat. Mus., 28, '85; *Brooks*, Biol. Lab. Stud., i, '79; *Dall*, Bull. U. S. N. M., 39, '92; Bull. U. S. N. M., 37, '89; *Howes*, Atlas of Biology; *Lankester*, Phil. Trans., '75; *Mc. Alpine*, Atlas Inv. Zool.; *McMurrich*, Biol. Lab. Stud., iii, '87; *Rabl*, Morph. Jhrb., '76, '79, '80; *Tryon*, Manual of Conchol; *Verrill*, Ann. Rep. U. S. F. C., '73, '87.

PART III.—CL. CEPHALOPODA.

LOLIGO PEALII* (*Squid, Cuttle-Fish*).

The squid is oceanic except as it frequents shores in search of food. It is used for bait by fishermen, and can be had of them or sometimes found in markets in seaside cities. The class is the most active and intelligent of the mollusks and contains some large and formidable animals. It is very important geologically because of the great development of the Orthoceras, Goniatite and Ammonite groups.

1. EXTERNAL ANATOMY. The body is divided into three regions two of which are closely related as is usual in Mollusks, the *head* and the *foot;* the other, *visceral region*, is somewhat distinct. The head is recognized by the location of the two large *eyes* and the *mouth* in the centre of the ten, sucker-bearing, tentacle shaped *arms*. The visceral mass is surrounded by a *mantle* within which and between it and the body is the *mantle cavity*. The body terminates posteriorly in the *fin*.

Examine the head and feet more closely, note the definite number of "tentacles" two are capable of great extension, note their position, study the suckers, note their number and arrangement, their *rim* and central *piston*, whereby they adhere; note the horny *beak* in the centre of the mouth; examine the eyes, noticing the *iris* and *cornea*, is there a lid?

**Brooks*, Invertebrate Zoology, '82; *Nicholson*, E. Brit. Art. Cuttle-Fish, '90.

Behind the head note the *neck* and the flap which extends around the neck opening towards the mantle cavity. The mantle fits against this causing the expelled water to pass out by the funnel on the ventral side, the *siphon*. Open the mantle cavity on the ventral side and note the *gills*, two in number; note at the opening to the siphon the black color, this indicates the location of the *ink bag* and the *vent*, their products pass out through the siphon with the expelled water. In the skin of the mid-dorsal surface there is a chitinous supporting structure, *pen*, imbedded in the mantle wall. Draw a general view.

2. INTERNAL ANATOMY. The mouth chamber contains a *radula*; the *throat* leads straight back to the *stomach*, a pair of *salivary-glands* open into the throat; the *liver* surrounds the throat with two ducts running back to the stomach. The *intestine* runs forward from the stomach on the ventral side and opens under the siphon; a blind pouch, *coecum*, leads back from the stomach to the hind end of the body. In the middle ventral line behind the arms, lies the *ink bag*, it opens into the intestine near the arms. The *heart* lies ventral to the stomach; it consists of a *branchial ventricle* at the base of each gill and a median *systemic ventricle* from which arteries can be traced in both directions; there are two anterior and two posterior *venæ cavæ*,both open into the branchial ventricles. The *kidneys* are similar to those of mollusca generally, two are present, each is a bent tube opening to (the pericardial cavity at one end and to) the exterior nearly in the middle line, a little behind the anus; each consists of a hollow chamber next the outlet and a glandular part closely investing the anterior vena cave. The *gills*, two in number (Dibranchiata) are made up of transverse plates placed on two stems which run their length, in one of these the blood passes from the *ventricle*, and on through the plates to be collected in the other, its vein leads to the auricle of the systemic heart; the water used in locomotion also serves to supply the gills and to remove excreta from the mantle chamber. *Nerve centres* homologous with those of other mollusks are concentrated in the head to form a *brain*; this is enclosed in a cartilaginous *cranium* and forms a ring of nervous tissue surrounding the throat; it consists of several masses which may be distinguished as follows: a *pedal* mass ventral and in front, sending nerves to the arms (and to the siphon) a *visceral* mass posterior to the pedal and sending nerves both to the mantle, to the "stellate ganglion" and to the viscera, and the dorsally located *cerebral* mass. Organs of *special sense* are present; most conspicuous are the two large *eyes*, having external resemblance to vertebrate eyes but not homolgous with them, they have a transparent *cornea*, an *iris*, a *lens*, and the concave inner side of the

spheroidal *eye-ball* is occupied with a *retina*, while on the side toward the brain, a number of optic nerves enter from a very large optic ganglion closely related to the brain. A small pit bordering on the socket of the eye-ball on the hinder side lodges ciliated and sensory cells connected with the brain and is called an *olfactory organ*. Cavities in the cranial cartilage (which originated by invagination from the surface in the embryo, contain *otolyths*, are connected by nerves with the cerebral mass, and) are supposed to be *ears*.

The sexes are separate, the gonads lie in the posterior end of the body, the germinal cells escape into the body cavity and thence by ducts to the mantle chamber.

BIBL.—*Brooks*, Mem. B. S. N. H., '80; *Lankester*, Ency. Britt. Art. Mollusca, '90; *Nicholson*, Ency. Britt. Art. Cuttle-Fish, '90; *Verrill*, Ann. Rep. U. S. F. C., '82; *Watase*, Stud. Biol. Lab., '88.

CHAPTER IX.—THE SUB-PHYLUM ANNELIDA *(Segmented Worms, Annelids).*

LUMBRICUS TERRESTRIS* (*Angle-Worm, Fish-Worm, Earth-Worm*).

Earth-worms are widely distributed. They can be had by digging or sometimes can be found on the surface at night after a rain. They can be killed by dropping them into a mixture of strong alcohol nine parts and hydrochloric acid one part, and either dissected at once (after rinsing in water) or preserved in alcohol (75 per cent. one day and 75 per cent. permanent solution). Living specimens should be examined to note their mode of locomotion, the definite location of the parts of the body as anterior and posterior, the dorsal and ventral surfaces, the maintainance of a constant equilibrium.

EXTERNALLY the body presents a somewhat cylindrical form; a larger *anterior end*, and darker *dorsal* surface; constrictions crossing it and dividing it into *somites* which are somewhat larger toward the front and are obscured, in some cases, in front of the middle by a thicker band, the *clitellum;* determine the number of the somites and the exact location of the clitellum; notice that the front somite is incomplete ventrally, *prostomium*. Note the hole under the prostomium, pass a probe into it, it is the *mouth*; note the *anus* in the center of the most posterior somite; find the short bristles, *setæ*, on the side of and beneath each somite, and note that those of the successive somites form a series through the length of the body. [There are openings too minute to be seen, on the somites on the ventral side as follows: of the *segmental* organs between the rows of spines of each side of each somite; of the *spermathecæ* on the line

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**Sedgwick* and *Wilson*, General Biology, '95 joining the ninth and tenth, and tenth and eleventh somites on each side near the mid-ventral line; of the *sperm-duct* on the fifteenth somite on each side, and of the *ovi-duct* on the fourteenth]. Draw views embodying these points.

The INTERNAL STRUCTURE of Lumbricus is more complex in the anterior part of the body, it is therefore best to cut off the anterior half and keep it for later study, and first to determine the antomy of the hinder part. The specimen should be pinned down dorsal side up, under water. With a sharp scalpel slit the skin open lengthwise taking care not to cut too deeply. Note the *body wall*; the *body cavity;* the *septa*, transverse partitions subdividing the cavity into compartments, corresponding with the somites; the thin-walled *intestine* which nearly fills the body cavity. Carefully pull the body wall aside and pin it down so as clearly to display the organs in the body cavity. Examine the intestine (and other organs) using the hand lens, and drawing it aside and cutting away part of it. Determine the following points: a vessel, the *dorsal blood vessel* runs the length of the intestine on its dorsal side; in some places it may be dark red from contained blood; in each somite it gives off two vessels on each side which encircle the intestine, and join a parallel ventral vessel directly below the intestine; [in live specimens in water this vessel can be seen through the skin to pulsate and the blood to flow forward].

The INTESTINE is hollow and contains black dirt (soil, mount some and examine, l. p.); its wall is thin and on the dorsal side is infolded, forming an organ, the *typhlosole*, which furnishes increased surface; the dorsal wall, on the body cavity side, carries light brownish tissue, the *liver*, not forming a distinctly separable organ; remove the intestine from part of the cavity and then examine carefully for the nervous system and segmental organs.

The *ventral nerve cord* is next the skin in the mid-ventral line; it runs continuously from somite to somite, through the entire body (except the first three somites); it is slightly enlarged in each somite, *ganglion*, and gives off fine threads, *nerves*, to the neighboring parts (faint lines in its centre indicate its two halves); a vessel, the *sub-neural vessel*, runs along its under side and gives off side vessels to the body wall, etc. Carefully remove a portion of the nerve cord, mount it in glycerine and determine these points more clearly. Draw.

The SEGMENTAL ORGANS are visible in each somite; they are at first likely to be confused with the cut ends of the septa, being of the same whitish color. They lie between the septa, one on each side, closely adhering to the body wall; they are slender tubes, seen, by teasing them from the wall under the hand-lens with a needle, to make several courses back and forth in the area of the two setæ of their side; (each tube represents, according to Wilson, five distinct parts; a ciliated funnel in the somite in advance, a narrow tube, also ciliated, a middle ciliated and pigmented tube, a wide tube, glandular and not ciliated, and finally the muscular part or duct, a sort of reservoir which opens to the exterior, through the body wall).

A view of the opened hinder end of the body should be made embodying all the points determined, and a cross section view should be made, either imaginatively from the dissection or from the study of an actual section, mounted for examination as a transparent object.

The ANTERIOR END should now be studied, opened under water, from behind, and pinned out as before. It is imperative that each somite should be numerically located, beginning at the anterior end, through all this dissection; in the second somite be careful not to destroy the small, white, dorsal, pear-shaped brain.

The DORSAL VESSEL runs continuously forward to the sixth somite, where it is lost in fine divisions running upon the pharynx: its *side branches* are numerous and fine in somites 18 and 15, and *single* in the remaining somites; in somites 11-7 the circular vessels are large and pulsatile, and are called *aortic arches*; in preserved specimens they are often gorged with blood. The *segmental organs* continue forward to the fourth somite.

The SEMINAL VESICLES belong to the reproductive system, but they are so noticeable that in dissection it is best to remove them before attempting to study the alimentary system. They are large white masses filling somites 9-15 and crowding the other systems out of view. Remove them after drawing so as to be able to include them later in a general view of their region of the body.

The ALIMENTARY SYSTEM, which, in all the posterior end of the body, is uniform in appearance in each somite, now varies considerably from point to point. The *gizzard* is a thick walled large part occupying somites 18-17: the *crop* is an equally large but thin-walled part in somites 16-15: cut open both crop and gizzard; the *gullet* is a much narrower tube, hidden by the aortic arches as well as by the seminal vesicles, running forward from the crop to the sixth somite; the *calciferous glands* are swellings on each side of the gullet in the somites 11-12; the *pharynx* is an enlarged and strongly muscular anterior part of the system, occupying the first six somites and opening anteriorly at the mouth; to see it remove the pin and carefully open the dorsal wall; be careful not to destroy the brain in the dorsal part of the second somite. There are no jaws or teeth in connection with the mouth.

The NERVOUS SYSTEM can be seen, by removing the pharynx, to present a continuation of the *ventral cord* up to the third somite; here it abruptly forks, a division running on each side around the pharynx, *œsophagæal collar*, to enter, on the dorsal side, a pear-shaped, whitish, small body, the *supra-œsophagæal ganglion*, or briefer, the *brain*; the two halves of the brain are so closely united as to appear almost as one organ, as are also the two halves of the ventral cord. There are no distinct organs of *special sense*, but the general skin is *tactile*, and the head is thought to be somewhat sensitive to light and in the pharynx there may be sensitiveness to taste.

The REPRODUCTIVE SYSTEM is hermaphrodite, but there is provision for cross-fertilization, through the fact that spermaries and ovaries are not active at the same time. The organs of reproduction are: The large white sperm vesicles already noted, [the *spermaries*, small, lying in somites 10-11, and closely connected with the sperm vesicles]; *spermathecæ*, small, white, round, attached to the ventral body wall on the junctions of somites 9-10 and 10-11, [*sperm ducts*, fine tubes running beneath the seminal vesicles to open into the exterior in somite number 15]; the *ovary*, a minute white, pear-shaped organ on each side near the mid-ventral line in somite number 13, and the *oviduct*, a ciliated funnel and tube, running from it through the septum to open in somite number 14, and the *clitellum*, (which is loosened from the body and slipped forward catching ova and spermatozoa as it passes the opening of their organs, and is slipped off over the head, closing as it does so, and thus forming a capsule containing the developing eggs.—*Wilson.*)

2. CHÆTOGASTER* (*Naid-Worm*).

Very small Annelids are frequently met in examining material collected in fresh water pools, from the surfaces of plants or from the sediment on the bottom. These under a power of 25 diam. are recognizable as Annelids by their distinct segmentation and the serial arrangement of setæ, but must not be confounded with numerous larvæ of true insects. A careful study of living specimens under slight compression will reveal many of the anatomical features of the Annelids. They are especially interesting for the study of *asexual reproduction*. As the somites are closely studied, decided differences are visible; in the centre a constriction is forming and will be found to contain at the time just before division, a brain and a ventrally placed mouth, and, in the middle of each half preparations for a still later division are visible. By keeping a single individual under continuous observation for several days the history of the process can be determined.

**Bourne*, Quart. Jnl., '91.

ANNELIDA POLYCHÆTA.

NEREIS LIMBATA*(?) (*"Clam-Worm"*).

Specimens on which this description was based were found in the mud, near low-tide level, on the shores of Oyster Bay in Long Island Sound. They appear, as to head, to coincide with N. limbata of Verrill's Vineyard Sound Report. Though found burrowing in the coarse gravelly mud, the animal is reported as observed swimming "with an undulating motion" — "in the day-time, in August, at Fire Island," where they were being devoured by fish in great numbers. I have found them in the stomachs of smelt and other fish.

1. EXTERNAL ANATOMY. The body shows distinct differentiations, dorso-ventrally and antero-posteriorly, and bears *cephalic appendages* and paired lateral appendages, *parapodia*. The *mouth* in front opens transversely; (or the *pharynx* may be everted through it and show a pair of laterally acting chitinous hooked *jaws*.) The segmented *body* is clearly divided into a narrower anterior and a broader posterior region; its *somites* should be counted; it tapers posteriorly, and at the end bears a pair of *tentacles*, called *cirrhi*, above which the *anus* can be seen. The *ventral nerve cord* can be seen through the ventral skin.

The HEAD presents a central pair of *tentacles*, borne at the apex of a small triangular *"prostomium;"* outside of them a pair of lobed or jointed *palpi;* behind these, on each side, four pairs of tentacle-like *cirrhi;* two pairs of simple eyes are located in the area between the cirrhi.

The PARAPODIA are complex outgrowths from the body wall. One should be cut off at its base, mounted (after staining) in glycerine and examined. It is a direct outgrowth of the body wall and not jointed at base; it presents a fleshy dorsal lobe or *gill*, with a minute dorsal *cirrhus;* two groups of long *setæ*, each supported by a long chitinous rod, *aciculum*, running in the fleshy tissue; smaller gill-like lobes connected with each group of setæ and a small ventral *cirrhus*.

2. The INTERNAL ANATOMY is less complex than in *Lumbricus*. The *alimentary system* consists of a protrusible muscular *pharnyx* with protractor and retractor muscular systems; a *crop*, on either side of which a (salivary) *gland*, whose duct runs into the pharynx, is located; the *stomach-intestine* is similar throughout, and there is no *typhlosole*. There are dorsal, ventral and sub-neural *blood vessels* and lateral branches from them, but no distinct set of aortic arches. The cavities of the somites, as in Lumbricus, contain a colorless corpusculated fluid, *blood*, (in some Polychætes this is red colored, but the corpuscles are white). *Nephridia* are present on the septa separating the somites. The *nervous system* is formed

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**Huxley*, Anat. Invert., '78.

essentially as in Lumbricus, and external special sense organs are present. There are no distinct organs of reproduction, *gonads*, but at certain seasons the epithelium on the lining of the cavities of the somites throw off cells which become the generative cells, and which escape by way of certain of the nephridia; the sexes are separate.

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CHAPTER X.—THE SUB-PHYLUM ARTHROPODA, CLASS CRUSTACEA.

A. THORACOSTRACA.

CAMBARUS* *sp.* (*The Cray-Fish*).

The cray-fishes, often inland erroneously called "crabs," are fresh-water animals, found in rivers and lakes, hiding in grass or under stones. They can be enticed out of hiding by pieces of fresh meat lowered among them, and caught in the hand or in a net. They are numerous in species, and are found in southern and central United States more commonly than near the sea-shore. In some places they are on sale in markets, the "tail" being used for food. The lobster, or even the larger shrimps, can be used in place of Cambarus in the following descriptions. *Living cray-fishes* should, if possible, be studied, both in their natural home and in a glass vessel, where their actions are better seen. Their natural attitudes, modes of quiet and excited locomotion, their degree of alertness, the uses of the various appendages for motion, sensation, feeding, defense, etc., should be seen. More rarely the operation of moulting may happen to be seen. All the points in the description can be determined from a single specimen, if care is used, but, where possible, two or more should be used, especially for the internal anatomy.

1. EXTERNAL ANATOMY. The body, covered with a hard shell of lime, presents two distinct regions, an anterior half, the *cephalothorax*, and a posterior half, composed of joints, the *abdomen*. Distinct dorsal and ventral surfaces are present, and springing from the latter along the entire length of the body are paired, movable, jointed *appendages*. The abdomen is terminated with a spreading *tail-fin*. Draw side, dorsal and ventral views.

The CEPHALOTHORAX is covered dorsally by an arched shell, the *carapace*, having: in front a pointed *rostrum;* in the middle a transverse line, the *cervical suture*, running obliquely forward and downward; and behind this and on the side a flap, *branchiostegite*, covering a chamber at the bases of the legs, containing the gills.

Huxley, Int. Sci. Ser., The Cray-fish, '80.

There are in this region, attached to the ventral surface, 14 pairs of movable appendages, subdivided as follows: two anterior pairs of *antennæ*, organs of special sense; one pair of *eyes;* five pairs of *pereiopods*, posterior, and used in walking, and to some extent in handling food; and six pairs of *mouth parts*, used in feeding. The two pairs of antennæ differ, the anterior being shorter and called *antennules;* each bears two short flexible *filaments;* the hinder antennæ have a broad *scale* at the base and a many-jointed filament, fully as long as the body. The anterior pair of pereiopods, *chelæ*, are greatly enlarged and bear snapping claws. Some of the other pereiopods are also chelate. In front of them there is a pair of jointed limbs, the *third maxillipeds*, the hindmost of the mouth-parts; the others are small and hidden by these. The *mandibles* are the first pair of mouth-parts; they are rounded, hard and close in the middle line, on each side of the *mouth*. There are openings to the *ears* in the basal joint of the antennules, to the green glands in the basal joint of the second *antennæ;* and the generative openings are in the basal joints of the third pereiopod of the female, and the last, or fifth, in the male.

The ABDOMEN is made up of six movably articulated *somites*, and the *tail-fin*. Each somite is completely covered with bone arched dorsally, *tergum*, so overlapped as to permit flexing the abdomen without leaving it uncovered; it is supported ventrally by a bony rod, the *sternum*, at the junction of which, with the tergum, there is a fold of bone, the *pleurum*. Each somite bears a pair of limbs, *pleopods*, used in swimming (and in the female in carrying eggs). Five are alike in the female, but the anterior ones are modified in the males; the sixth pair, considerably modified, form the lateral portion of the tail-fin; its central portion, the *telson*, is in the series of the somites, and on its ventral surface the *anus* is located. Fill out the drawings previously made to include all these additional points.

2. INTERNAL ANATOMY. In a specimen which has just been killed (with chloroform), or in a preserved cray-fish, carefully remove the carapace (cutting forward to the base of the rostrum) and the abdominal terga, pin down in water, back up; using a probe to separate but not dislocate the organs, recognize: the *body cavity*, in which the various organs lie; the *stomach*, large, thin-walled, median, reaching from just behind the rostrum to the level of the cervical suture; the *mandibulary muscles*, fibrous masses lying on each side of the hinder portion of the stomach, and running down to the mandibles; the *liver*, long, glandular, lying ventrally in the body cavity on each side, and reaching from the front end of the stomach as far back as the abdomen; the *heart*, angular, white,

just behind the stomach and directly beneath the carapace (it is often removed with the carapace, unless great care has been taken); the *intestine*, a long tube running mid-dorsally the length of the abdomen; the *flexor muscles* of the abdomen, fleshy fibrous tissue filling the somites ventrally; [the *extensors* of the abdomen, in the dorsal skin of the abdominal somites; the *dorsal aorta*, lying above the intestine and closely related to it.] Draw, a view showing all these points.

[The HEART is in connection with the following vessels, some of which can perhaps be seen: one median anterior *ophthalmic* artery; a smaller anterior artery on each side, *antennary* arteries; a middle posterior *dorsal aorta;* and, running downward from it mid-ventrally, the *sternal* artery; the sides of the heart are perforated by openings, *ostia*, which lead to its cavity and are inwardly guarded by *valves;* there are no auricles, the blood coming freely into the *pericardial* chamber, in which the heart lies, directly from the gills. Remove the heart after noting these points.]

The REPRODUCTIVE SYSTEM is located directly under the heart; it differs considerably with sex. After deciding whether your specimen is a male or a female, by examination of the first two pairs of pleopods, and by the location of the openings of the system on the pereiopods, make out the following points: in the male, the whitish, finely granular *spermary*, median in position; the *vas defferens* or *spermduct*, one to each side, a convoluted tube, running downwards to end in the bases of the fifth pereiopods; in the female, the *ovary*, in breeding season, considerably enlarged, red in color, and composed of large and distinct rounded *ova;* the oviducts on each side running down to end at the bases of the third pereiopods; in addition females may have numerous eggs, "*spawn*," attached to the pleopods, where they are carried till the young hatch and escape. The reproductive organs should be carefully removed after making drawings to show the parts and locations. The spawn should be removed and examined; if two black spots are seen they are the eyes of the embryo, whose large anterior body and small abdomen may be visible.

The ALIMENTARY SYSTEM can now be examined. (If the water has become turbid change it and keep doing so as fast as necessary). Displace the stomach gently and find below it a tube, the *throat*, running down to the *mouth*. Note behind the stomach a smaller rounded organ, the *pylorus*, and on each side of this, a very short *duct* leading in from the liver; trace the intestine from the pylorus, where it is ventral, to the dorsal surface and back to the anus. Open the stomach and examine its interior, noting its *chitinous* walls and dorsally and posteriorly the hardened bones for pulverizing the food, *gastric mill.* Remove these parts and make a side view of them. Remove the two liver masses, noting that they are free from the organs, except the pylorus; examine them and note their structure of small tubes related to a central duct. [Sections of the liver display the secreting cells and their arrangement and will repay study. Sections of the intestine show epithelium and striped muscular tissue.]

The EXCRETORY SYSTEM is displayed after the stomach has been removed; it is the *green gland*, or *nephridium*, a flattened, rounded organ at the lower front surface of the stomach, in the base of the second antenna; its opening to the exterior has already been noted; [it has also an opening into the body cavity, and is thus homologous with the segmental organs of annelids]; (sections show that its walls are differentiated as glandular and duct portions).

The RESPIRATORY SYSTEM is brought to light by removing the branchiostegite; it consists of filamentous organs, the *gills*, located in a space, the *gill chamber*, open to the water at the ends and beneath. Note the exact number and location of the gills, and then examine one closely and see its central stem and hollow side filaments in which the blood is exposed to the gases of the water. At the front end of the series note the *scaphognathite*, a curved piece lying in the line of the cervical suture; it is a part of one of the mouth-parts, and is used to force a current of water through the gill chamber.

The MUSCULAR SYSTEM is too complex for detailed study; some of its members have already been noted; in addition there are muscles used in the movements of the stomach wall, and the muscles of the appendages; these latter will be found inside the joints of the appendages, where they, by contraction through *tendons*, move the distal or more remote joints. The chela should be opened and the large muscle inside examined; its *fibres* run obliquely from the central tendon to the wall of the joint; by their contraction they pull the tendon and through it the snapper. Make a diagram to show the mode of action of this muscle. The *mandibulary muscle* is similarly related through a tendon to the mandible. [Fibres of the cray-fish muscular tissue, mounted and examined with the microscope (x300 diam.) show the characteristic "striation" very clearly].

The NERVOUS SYSTEM consists of a *brain*, directly below the rostrum, close to the ventral and anterior body wall; two nerves, embracing the throat, *circum-œsophagæal collar*, a *ventral chain* of ganglia in the cephalothorax, covered by bone, and an *abdominal chain*, easily found next the skin and below the flexor muscles.

Draw views showing the internal anatomy of Cambarus, both from the side and dorsally, and index fully.

3. DETAILED STUDY OF THE ADDENDAGES is preliminary to any insight into the "morphology" of the crustacea, they must be removed from the body at their very base, so as to include all of the limb, and care must be taken to avoid any possible confusion of idea as to their position in the body. The smaller ones should be examined under water with a hand-lens or low-power; drawings should be made and arranged on the page in the relation of the limbs in the body.

Examine the HINDMOST PEREIOPOD and notice that it is made up of a number of separate segments of various shape and size, and moving on each other in various planes. Remove the branchiostegite, if you have not already done so, and look for the junction of the fifth pereiopod with the body. When you have found this, cut the appendage away at the joint; notice that it has no gill on or above it. Its joints are called, beginning at the base: 1, *coxopodite;* 2, *basipodite;* 3, *ischiopodite;* 4, *meropodite;* 5, *carpopodite;* 6, *propodite;* 7, *dactylopodite.*

Draw the appendage from the hinder side and index.

Remove the other pereiopods of the same side, being careful to take the gill with the coxopodite, and keep the limbs in order. Arrange them in a row in front of the fifth, and draw them all, and indicate the corresponding parts by the same refererence letter. Examine the last two joints in each limb especially and note on which there is a snapper, and draw the figure to show the transition in shape from the last to the first. Note that there are only six movable joints in the first pereiopod, seek for indication that two have fused to form one. Where is this line of fusion located?

THE MOUTH PARTS. Remove the limbs in front of the chelae, working from behind forwards. Those next the mandible are very delicate, and require very careful manipulation. Make the drawings as you remove them, *do not remove all first, and then draw all.* The THIRD MAXILLIPED presents two portions; one, the *endopodite,* toward the middle line, it is composed of several joints, and resembles the hinder pereiopods in number of segments; the other, the *exopodite,* consists of a long unjointed *proximal* piece, nearest the body, and a *distal* filamentous many-jointed piece. These two portions of the limb arise from a single basal portion, *protopodite*. The exopodite and endopodite do not arise directly from the body but from a joint, *basipodite,* which articulates with a second joint, the *coxopodite,* articulated to the body. The endopodite consists of five parts, named as in the pereiopods, the first, ischiopodite being fused with the basipodite.

The SECOND MAXILLIPED is closely comparable with the third but differs in form of endopodite, it being shorter, and more like a mouth part; it has all the joints of the other, but some are very small, the ischiopodite is short, and the carpopodite and dactylopodite are very small. The FIRST MAXILLIPED retains an exopodite like that of the second, but the endopodite is reduced to a very small rudiment, so hidden by the exopodite as to be at first easily overlooked. The maxillipeds thus present a very distinct transition between the pereiopod and the maxilla type of limb.

The SECOND MAXILLA, as regards the basal portion and endopodite closely resembles the first maxilliped, the exopodite is wanting as such but is represented by a part of the scaphognathite. The *coxopodite* and *basipodite* are both nearly subdivided by a deep incision upon their inner side. The FIRST MAXILLA is easily detached with the second; and if not found in place should be sought there. It has no exopodite but small, leafy coxopodite and basipodite and a short rudimentary endopodite are present.

The MANDIBLE presents a strong, transversely elongated *protopodite*, hardened and denticulated on its inner edge where it meets its mate; it bears a three-jointed *palp*, the endopodite; the exopodite is wanting.

The SECOND ANTENNA presents a *coxopodite*, bearing the pimple-like orifice of the green-gland, a *basipodite*; a flattened piece, *squammule*, the exopodite; and an *endopodite*, consisting of three basal joints and the long, many-jointed flexible distal part. The FIRST ANTENNA or *antennule* presents a *coxopodite*, in whose basal joint the *ear* is situated, and two joints bearing distally two short, many-jointed *filaments*. Examine the basal joint and note the deep groove where the entance to the ear is located. Carefully cut away the shell on one side of this joint and explore the interior with a needle, under a lens, and find a thin walled chitinous sack, it is the ear, remove it and mount it in water and examine (x 30 diam.) it contains a curved ridge of peculiar *auditory hairs*, and a number of fine crystalline grains, *otolyths*. Draw and index.

The eyes are stalked and movable and thus serial with the other appendages. Each presents a *stalk*, light colored and movable, upon the end of which is a dark portion, the *sensory surface*. Remove one eye, moisten and wipe off the sensory surface and examine it with the hand lens. It is marked by very fine lines, which are in two sets, at such angles with each other as to divide the surface into many minute diamond shaped areas or *facets*. Notice that these markings are confined to the sensory surface. There are no simple eyes.

THE PLEOPODS.* The first five (in the female) are alike and consist of: a rudimentery coxopodite and an elongate basipodite; an exopodite and similar endopodite, each with a long proximal portion and a many-jointed filamentous distal portion. The *sixth pleopod* is considerably modified, but the primary appendage scheme is clearly traceable. We find: the *basipodite* (coxopodite absent, a rudiment is present in the Lobster,) and the broad flattened *exopodite* and *endopodite*, so placed as to assist in the backward darting motions of the animal when pressed by its enemies.

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*The pleopods in the cray-fish, owing to the development of the pereipods and the habits of walking, are less important relatively than in the shrimps, in which the primary swimming habits are still prominent.

Drawings of all the appendages, exhibiting their points of comparison and fully indexed, should by all means be made as a part of the study of the appendages.

CALLINECTES HASTATUS (*Edible-Crab*).

The edible crab is very common in the waters of the Atlantic coast of this country, especially in the latitude of the Middle States. It is extensively marketed and can be generally had through the fish dealers. All of the brachyura are marine, hence not accessible inland. Any of them can be used in a comparison with Cambarus, if Callinectes is not accessible.

The body at first seems to be very different from that of the crayfish, but close inspection shows that this is not a radical difference but due to the rudimentary condition of the abdomen. This region in the male is narrowed to a very slender piece, so closely folded beneath the carapace as to seem a part of it. It contains the intestine, the anus being located at its tip, as in Cambarus, and its anterior appendages are retained, being used in copulation. In the female the abdomen is less reduced and retains its segmentation, and the appendages, which are used in spawning. The form of the carapace is changed, being shortened and broadened, but its relations to the internal organs is the same. The appendages, too, are somewhat though less modified; the antennæ are shorter; the mouth-parts are crowded into a space covered in by an operculum formed of the modified third maxillipeds. In Callinectes the fifth pereiopods are flattened and used as sculls in a lateral swimming mode of locomotion.

EUPAGURUS POLLICARIS (*Hermit-Crab*).

The hermit crabs of several species are common on the shores of the Atlantic. They have the habit of dwelling inside of the empty shells of dead sea-snails. Several modifications of structure are found in them which are clearly correlated with this habit, and they amply repay a close study with reference to it. The description of Cambarus will furnish an outline to follow, and the differences found should be thought of in connection with the peculiar mode of life of the hermit to find a relation between them if possible.

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B. ARTHROSTRACA.

ONISCUS *sp.* (*Sow-Bug, Pill-Bug*).

Most Isopods are marine, but a few are not; some of the marine ones are only partially aquatic, since they commonly run over stones and wood-work of wharves, and seem to be perfectly at home out of water. Sow-Bugs are very common in damp places under boards. They can be studied at once after killing, or can be preserved in alcohol for later use.

THE BODY is oval, depressed and composed of a number of somites; its divisions, which do not at once seem to agree with those of the Cray-fish, are a short anterior *head*, seven equal *thoracic somites*, and six *abdominal somites*, the first two much smaller than the rest. Numerous *appendages* are visible on the ventral side, chiefly in the thoracic region, and in females at times eggs, or partially developed young, are carried in a brood chamber beneath the abdominal somites. Draw an enlarged dorsal view.

THE HEAD should be removed from the body for close study. It presents: a pair of *eyes*, not stalked but *sessile*, each consisting of a small number of strongly convex *facets;* a single pair of unbranched second *antennæ*, consisting of three short basal and several longer distal joints (the first antennæ, usually present in this Order, are wanting in Oniscus), and the *mouth-parts*, of which a pair of maxillipeds, fused in the middle line cover in the rest, viz.: two pairs of *maxillæ* and one pair of *mandibles*. Draw these parts, and in addition, if time permits, separate and draw the mouth-parts.

THE SEVEN THORACIC SOMITES are alike except in size; remove the first and clean off the flesh and note: its broad depressed *tergum;* the narrow *sternum;* the broad *pleurum;* the limb, unbranched and composed of five joints and a terminal claw. Draw and index.

THE ABDOMINAL SOMITES should be separated under water. Notice that: the *first two* are very narrow and lack pleura; and they have thin lateral flaps, modified limbs, which serve as *gills;* the *following three* have pleura, which meet those of the thorax and and complete the outline of the body, and they bear gills like those of the first two somites; the *sixth somite* of the abdomen is triangular-pointed behind, and bears a stiff appendage consisting of a basal piece and a narrow single inner and a two-jointed flattened outer portion. Compare this with Cambarus. Draw views showing these facts.

GAMMARUS (*Sand-Flea*).

After completing a dissection of *Oniscus*, it should be compared with *Gammarus*, the sand-flea, or some other member of the S. O. Amphipoda, either by the study of the animal, if possible, or by means of illustrations. In GAMMARUS the body is compressed and the form resulting is outwardly very different, but upon analysis a similar division of the body into regions and a closely similar appendage scheme will be detected. Both should then be compared with Cambarus and the Thoracostraca to detect the identity of appendage scheme with the difference in the thorax as to fusion or segmentation. The free-somited thorax is a very primitive condition, but the sessile eye and uniramous type of limb is very divergent from the primary form for the Malacostraca.

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C. ENTOMOSTRACA.

BRANCHIPPUS.

Branchippus is one of the most interesting of the crustacea because of the primitive condition of its body, and appendages. It is found in various places in fresh-water ponds; it is about an inch long, and swims gracefully, generally with its ventral surface upward. There are three distinct regions of the body: an anterior *head*, a middle *thoracic region* and an *abdomen*. The middle region is divided into somites, each bearing a pair of jointed *leaf-like limbs;* there is no coalescence and no carapace, and the animal has thus distinctly a more annelidan look than any other of the crustacea. The head, in addition to the compound eyes, bears a single median *simple eye;* there are two pairs of antennæ, there is a mandible, there are eleven pairs of similar limbs, each having a bilobed distal portion, and whose inner and outer portions bear resemblance to the exopodite and endopodite of the higher crustacea, while the basal part bears a gill. The abdomen (of nine somites) is destitute of appendages. The larval form of Branchippus is found with the tow-net and is a "nauplius."

There are allied Phyllopods, of which Apus and Estheria are the leading genera. In the latter there is a carapace which is so developed as to form a bi-valve shell.

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CYCLOPS *sp*.

Specimens are found by skimming in fresh-water, ponds. They are universally small (1-8 in. long); they are recognizable by their sudden darting motion; a number of points can be seen with the hand-lens, but they need the compound microscope for adequate examination.

Capture a specimen by means of a pipette or otherwise and place it in the centre of a slide; put a scrap of paper on each side to support the cover class; cover and surround with water, and determine the following points:

The elongate bilaterally symmetrical *body* is divided into two regions: an anterior, *cephalothorax*, and a posterior narrower *abdomen*. The oval *cephalothorax* is covered with a *carapace* in front, which is followed by three (or four) free somites; the abdomen consists of five somites, destitute of appendages and terminated by a forked tail--(at the breeding season females carry an oval egg-sack on each side of the second abdominal somite.)

There is a single median *eye* in the front end of the body, and no compound eyes; there are two pairs of *antennæ*, the first are very long and used in locomotion. (The remaining appendages are: a pair of mandibles without palps, two pairs of two-branched maxillæ used in mastication, two pairs of maxillipeds, five pairs of thoracic feet, each two-branched and furnished with plumose swimming hairs.)

Despite its minute size the internal anatomy of Cyclops is complex and similar in general to that of the crayfish. The mouth, stomach, straight intestine and terminal anus lie in the middle line of the body; dorsal to this system is the sack-like heart (not present in all Copepods) there are no gills, or special excretory organs; an anterior cephalic ganglion, a collar around the throat and a ventral nerve gangliated chain are present; the gonads lie in the cephalothorax and open on the second abdominal somite, the eggs develop into a peculiar *larval form* having a single median eye and three pairs of appendages, all used for locomotion, *nauplius stage*. A large number of the copepods are more or less parasitic and correspondingly degenerate.

BIBL.—*Woodward*, E. Britt. Art. Crustacea, '90; *Herrick*, Crustacea of Minnesota, in Minn. Geol. Nat. Hist. Survey '95; *Rathbun*, Proc. U. S. N. M., V. 10, '88.

CYPRIS *sp.*

The ostracods are obtainable from sediment from the bottom of a fresh-water pool which has been allowed to stand several hours. They are seen as minute roundish often green-colored animals actively running over the bottom of the vessel. The specimen may be captured and prepared for examination as in Cyclops, and the following points can be determined with the hand lens:

The BODY is enclosed in a *bivalve shell* which is *hinged* on one margin (dorsal); at one end short *appendages* are thrust out and swept ventrally, they are the *antennæ*, the unjointed body is attached to the shell anteriorly and dorsally, and is free posteriorly and terminates in a forked *tail*, used as a kicking organ. There is in front a single median eye. The appendages are two pairs of locomotive *antennæ*—a *mandible* with palp—two biramous *maxillæ* and two uniramous *thoracic legs*.

[1] **BIBL.**—*Herrick*, Entomostraca of Minnesota '95.

CHAPTER XI.—CL. ARACHNIDA.

OR. ARANEÆ, *sp.* (*Spiders*).

Material for study of the anatomy of spiders can readily be obtained, it can be used at once after killing (in alcohol or with Chloroform, or otherwise) or can be preserved in alcohol for future work. The habits of live spiders will amply repay close and prolonged observation. Their extreme agility, wariness, their trap and nest building habits, all indicate a high degree of intelligence as well as finely organized muscular system. The balls they often carry about are their eggs.

The BODY presents two globular regions, *cephalothorax* in front with the long, slender *walking limbs*, and the *abdomen* behind, attached to the cephalothorax by a slender junction and not bearing obvious limbs.

THE CEPHALOTHORAX is divided by a *cervical suture* into front and hind portions; there are *no antennæ* and no *compound eyes;* there are four pairs of small glistening *simple eyes* (in some cases, two may be so close together, as to seem one, some may not be visible from the dorsal side); in many cases the skin is highly colored.

THE APPENDAGES are six pairs, viz: the *chelicerae* in front having a large basal joint and a sharp-pointed terminal piece, shutting back on it like a knife blade (this is perforated and leads to a poison gland at the base of the limb); the *pedipalpi*, slender limbs of six joints, the terminal joint swollen in the male; the four *walking legs*, seven-jointed, the terminal joint bearing the minute, comb like claws on their tips for grasping the web.

THE ABDOMEN is unsegmented and lacks distinct appendages, but bears at its tip two or three pairs of minute papillæ, the *spinnerets;* (in some cases indications of the segmentation of the abdomen are visible; in embryos the abdomen is distinctly segmented, and each segment bears a pair of rudimentary limbs, none of which save the spinnerets develope.)

OR. PHALANGIDA (*Harvest Spiders, Daddy-Longlegs*).

The name "daddy-longlegs" is the common American name for this order, in England the same name commonly refers to a family of flies, the "Tipulidæ" with small body and very long legs. Specimens are found on walls and dry boards, often under boards.

THE BODY is divided into an anterior unsegmented part bearing limbs as in the spider, *cephalothorax;* but is connected by means of a broad attachment to a distinctly jointed *abdomen* (of 6-9 somites). There are two (or four) simple eyes located in a low spine in the centre of the dorsal surface of the cephalothorax. The limbs are in six pairs—a pair of chelate *chelicreæ;* a pair of elongate *pedipalpi;* and four pairs of very long and slender *legs*, these are theoretically seven-jointed, but the basal *coxa* is fused with the body; the free joints are a short *trochanter*, followed by five parts, the last made up of a large number of very minute movable pieces and terminated by a claw.

OR. SCORPIONIDEA (*Scorpions*).

Members of this order are confined to the hotter parts of this and other countries, they are found in Texas and Lower California. If they are not obtainable their external anatomy can be made out from figures. (E. Britt. vol. ii, p. 283.)

The BODY is divided into three regions, a *cephalothorax*, equivalent with that of the spider; smaller than the abdomen to which it is broadly joined, and which bears six pairs of jointed limbs. The abdomen is seven-jointed, and is followed by a "tail," the *post-abdomen*, a region not represented in the spider; it is five-jointed and terminated by a segment bearing a *sting*. Simple eyes are present, a pair in the centre of the carapace and three pairs on its front border on each side. The limbs are six pairs in number. The anterior pair are *cheliceræ*, they are chelate and hardly visible dorsally; next them are a pair of large, strong clawed *pedipalpi;* there are four pairs of six-jointed walking legs.* The second abdominal somite bears peculiar comb-shaped appendages called *pectines*, they have a serrated posterior border. In front of these on the first somite there are small flaps, called *opercula* which cover the genital openings. Large stomata are present on the ventral side of four abdominal somites, they lead to respiratory cavities, called lungs.

BIBL.—*Cambridge*, Art. Arachnida, E. Britt., '90; *Lankester*, Quart. Jnl. Mic. Sci., xxi; *McCook*, Spiders of North America; *Moggridge*, Trap-Door Spiders, '78; *Morgan*, Biol. Stud. J. H. Univ., '91; *Weed*, Am. Nat., '90; *Wilson, E. B.*, Ann. Rep. U. S. F. C., '78; *Van Beneden*, Animal Parasites, Int. Sci. Ser.

CHAPTER XII.—THE CLASS INSECTA.

A. MYRIAPODA.

LITHOBIUS† *sp.* (*Thousand-Legged Worm, Centipede*).

Found in rotten wood, under stones and damp boards; there are two distinct orders, the Millipedes, e. g. Julus, cylindrical and with many somites; and the Centipedes, e. g. Lithobius with few somites, flattened body, all the northern forms are harmless.

THE BODY, elongate and parallel-sided, presents a distinct *head* (not cephalothorax) and a posterior region not divided into *thorax* and *abdomen*, which consists of a number of similar *somites;* the flat, broad *head* bears a pair of obvious *antennae*, long and many jointed (short and seven-jointed in Julus); two (paired) groups of simple eyes, each composed of a few rounded *ocelli*, and on the under side, the *mouth parts*, which consist of an *upper lip;* a pair of strong, biting *mandibles* without palps; two pairs of *maxillæ* each with palps, the anterior shorter and blunt and used in biting; the first pair of legs, *maxillipeds*, are also closely related to the head and have a median portion which forms an *under lip*, and a four-jointed, strongly curved *poison claw.*

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*A coxa present but fused with the body and makes seven theoretical joints.

†*Moseley*, Art. Myriapoda, E. Britt.; *Bollman*, Proc. N. S. N. M., V. 10, iii, '88; *Cook*, Proc. U. S. N. M., Vol. 13, '91.

THE SOMITES, fifteen in number, present a broad, flat ventral *sternum*, a similar dorsal *tergum;* the terga are not equal, some being smaller than others; the somites are flat and broad and there is *no pleurum*, the side wall being fleshy; the limbs are articulated at the hinder border of the sternum, and in the fleshy side wall of some of the somites, over the origin of the leg, there is an oval opening guarded by chitinous shell, the *spiracle* or entrance to the respiratory passages.

THE LEGS are one pair to each somite (the same for the reduced as for the other somites, c.f. Julus). They are similar throughout the body, save that the last pair which border the generatve opening are greatly reduced in size, and two pairs which preceed them, are considerably increased and consist of about seven joints.

[IN THE MILLIPEDES *(Julus)* the *antennæ* are short and seven-jointed, the *maxillæ* are fused to form a single plate, and the hooked *maxillipeds* are wanting, the somites are complete rings of chitine and have a distinct pleurum, the anterior three (thoracic) bear a single pair of limbs, the remaining bear *two pairs* (being two fused somites) the body is closed at the hind end by two chitinous plates which meet in the middle line].

B. HEXAPODA.

CALOPTENUS SPRETUS *(*Grass-Hopper*).

EXTERNAL ANATOMY. THE BODY is obviously divided into three regions: the *head*, with antennæ, mouth parts and eyes; the *thorax*, with three pairs of walking legs and two pairs of wings; the *abdomen*, segmented, and not bearing obvious appendages.

THE HEAD should be removed from the body and its parts closely examined and drawn. It presents a pair of *compound eyes*, oval, convex, lateral, their surface regularly marked into minute six-sided areas *facets;* three *simple eyes*, one in the middle of the front of the face and one over the base of each antenna; a pair of *antennæ*, (mount one on a slide and study h.l.) consisting of a *basal* joint and a number (how many?) of *distal* joints, and *mouth parts* which require careful dissection and study.

**Brooks*, Invert. Zool.; *Packard*, 3d Rep., N. S. Ent. Com. '83.

THE MOUTH PARTS should first be located *in situ*, viz: the *upper lip* in front; the *lower lip* behind, *labrum*, bearing on its side a jointed palpus; the *mandibles* visible on the side of the face, and just beneath the upper lip; the *maxillæ*, just in front of the labium, with a longer jointed palpus. After drawing a front view of the head to show as many of these points as possible, remove them and make out the following additional points: the *labrum*, its median part of two (fused?) halves, each bearing a three-jointed palpus; the *maxillæ*, each consisting of two larger pieces, the basal *lacinea*, toothed on its inner margin, and the outer *galea*, rounded at the edge and bearing a five jointed palp; the *mandible*, a short, heavy, biting appendage; the upper lip divided into an upper portion. *clypeus* and a rounded and indented free lower portion the *labrum*.

THE THORAX is divided into two distinct parts, viz: the *prothorax*, bearing the front leg; the *meso-meta-thorax*, imperfectly sub-divided and bearing two pairs of legs and two pairs of wings. Remove the thorax from the rest of the body; clean off superfluous flesh and notice: the *pronotum*, a saddle shaped piece, the tergum of the free pro-thoracic somite; the free, small mid-ventral pro-thoracic sternum; the pro-thoracic leg, made up of the following joints: *coxa*, a small basal joint, *trochanter*, small and closely united with the coxa; the *femur*, long and and cylindrical; the tibia long and slender; the tarsus, long, several jointed and ending in two curved claws, *ungues*, and a suctorial, soft pad, *pulvilus* Draw enlarged views.

THE MEOS-META-THORAX. Examine the body at the points of origin of the wings and legs; note the constrictions indicating *somites*, two *terga* and two *sterna* can be distinguished; oblique lines cross the sides of the region, the deeper one running up to a point between the bases of the wings, marks the junction of the somites. Each somite, as thus bounded, bears a pair of legs and a pair of wings. On the front and side of each somite a small oval *spiracle* can be seen; with a needle it can be found to be an opening guarded by two small shelly pieces. Study both MESO-LEGS and META-LEGS and compare them with the front leg; note their different mode of action on a living specimen; note that the hind leg, which is modified for leaping, is strictly similar structurally to the others; compare it with the jumping limb of the frog and kangaroo. Draw comparative views.

THE WINGS should be examined (with h.l. after mounting on a glass slide). Do they differ? How is the front one used? On the hind wing note: its thin, transparent, membraneous texture; its triangular outline; the *veins* which run radially from its base to the outer border; the *veinlets* which cross between the veins; its stronger border and the radial lines by which the wing folds (like a fan). On the fore-wing note the narrow shape, uniformly hard texture, close venation; draw comparative views of both wings.

THE ABDOMEN is composed of distinct somites (how many?), of which the first is incomplete laterally and below, and carries on each side an oval patch covered by a very thin membrane, the *ear;* a *spiracle* lies just below the ear; the remaining somites, except the terminal ones, have a *sternum*, a very narrow *pleurum* and a strongly arched *tergum*, and a spiracle on the lower anterior corner of each tergum; the *terminal somites* differ in the two sexes. In the *female* it is elongate and is modified for use in depositing eggs, following the eighth somite, the following parts can be made out (acc. to Brooks) three incomplete terga, the last underlaid by small ventral pieces, *podical plates*, between which an opening (of the oviduct) is bounded by the *ovipositor* presenting an elongate dorsal and ventral portion for opening a passage in the soil, and the median *egg guide* of shorter pieces. In the male the abdomen is shorter and rounded at tip, a common sternal plate is present for the ninth and tenth narrowed somites, the eleventh tergum is short, and subtended by a ventral bilobed sub-genital plate, between them several smaller pieces, *podical plates* and *cerci* are traceable; draw side views of both sexes.

INTERNAL ANATOMY.* The BODY WALL is a thin chitinous layer. enclosing the organs, in the space between the wall and the organs fatty tissues is often present. [THE HEART, which is elongate with openings into it at regular intervals, is so closely related to the dorsal wall that it is likely to be destroyed in opening the specimen.]

THE OVARY, in the female, occupies most of the dorsal anterior portion of the abdomen, first notice that it is made up of many similar sloping oval pieces, *eggs*, then remove the ovary, and mount a few of the component parts and note on the summit of each a fine thread, this contains *immature eggs*, (which can be seen in a glycerine mount under the compound microscope).

The AILMENTARY SYSTEM should be carefully separated from the rest of the organs and removed to clear water for careful examination, several organs can readily be distinguished, viz: the *crop* in front continuous with the *stomach* behind and the *gastric cæca* eight spindle-shaped pouches opening at the junction of the crop and stomach; the smaller tubular *intestine* follows the stomach, and the *malpighian tubules*, excretory organs, innumerable fine threads arise at the junction of stomach and intestine; the somewhat enlarged *rectum* at the tip of the abdomen terminates the canal. *Salivary glands* lie in the thorax, they are connected by means of a duct with the mouth chamber.

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*Pin a fresh or alcoholized specimen onto the bottom of a dissecting pan, back up. Slit down the thorax and abdomen and pin the walls of the body apart on either side. All the dissection must be made under clean water. Separate the organs carefully with needles.

[THE RESPIRATORY SYSTEM consists of air-tubes, *tracheæ*, which lead inwards from the spiracles and from which small tubes ramify to all parts of the body].

THE NERVOUS SYSTEM consists of a *brain*, a *collar* surrounding the throat, and a *ventral chain* of three thoracic and five abdominal gangiia.

LARVAL STAGES. YOUNG GRASSHOPPERS can be caught in a net (of cheese cloth fastened to an iron frame 8 x 11 inches square)drawn through the grass. They are about ⅛-inches long at first and in general resemble the adult, head and thorax being well formed except the wings, the abdomen is less advanced. Intermediate stages with half-grown wings and with the terminal organs of the abdomen advancing in growth can also be found and the steps of development traced.

OTHER HEXAPODA.

So much interesting morphological work can be done on readily obtained material, that after a student has acquired a knowledge of the grasshopper it will pay him to compare with it the external anatomy of both adult and larval forms from as many different orders and families of Hexapods as possible. A few directions and suggestions are added but the similarity is obvious enough to enable a student to work out the details largely for himself.

1. GRYLLUS (THE CRICKET), observe in the field, their home, their usual mode of locomotion, do they usually leap, ever fly? Compare in detail with the grasshopper, do you find any hind wings? Draw views of cricket to compare with the grasshopper.

2. THE KATY-DID, compare in detail with the grasshopper and draw comparative figures.

3. SQUASH-BUG (can be found on many flower clusters); observe broad, flat, angular shape, small head, large triangular pronotum, and the abdomen protected by the hardened anterior wings. Search the head for antennæ, eyes, mouth parts. The mouth parts are greatly modified and form a piercing and suctorial tube, made of the elongated *labium*, its edge rolled up, and the elongated, slender *mandibles* and *maxillæ*, which at their tips are very sharp and serrated. The legs are all similar and subdivided into joints, like those of the grasshopper. Compare the wings with those of the grasshopper, the hardened condition of the base of the fore wing gives the name "hemiptera" to the order.

4. THE DRAGON FLIES are interesting for their aquatic larval life, as well as for their adult peculiarities. The adult body presents the usual subdivisions, the head bears a pair of *compound eyes*, very large and strongly convex and three *simple eyes*, a pair of short and hairlike but jointed *antennæ*, and a biting *mouth;* the *prothorax* is rudimentary but bears a pair of slender front *legs*, the rest of the thorax is large and bears two pairs of slender *legs* and two pairs of *wings*, the latter are finely veined, equal in form and texture and are not capable of folding. The *abdomen* is jointed, is very long and slender, the whole animal is very light and delicate as related to its strictly aërial mode of life.

THE LARVAL STAGES can be found on aquatic plants. The larva has a large *head* with a powerful *jaw* concealed in a modified *under lip*, three pairs of *walking legs*, two pairs of rudimentary undeveloped *wings*, a jointed *abdomen* and in some (e. g. Agrion) there are extensions at the tip of the abdomen filled with air tubes which are used in respiration. The larvæ at the time of transformation creep up the stems of rushes into the air where the body shell splits open down the dorsal side and the perfect adult insect emerges leaving the empty shell behind.

5. DORYPHORA DECEM-LINEATA *(Potato Beetle). A*—ADULT. Three regions are recognizable but with considerable unlikeness to the grasshopper, *head* being very small, *pronotum* large and the anterior wings, *elytra* developed so as to cover the abdomen dorsally and half laterally. Few-facetted *compound eyes*, no simple eyes, and two short *antennæ* of numerous joints are present. The *clypeus* is short, giving view of the stout, biting *mandibles; maxillæ* and *labium* are closely like those of Caloptenus. There are three pairs of nearly equal *legs*, short and stout, they have the usual number of divisions, compare them with those of Caloptenus. Examine the wings, the anterior are modified into *elytra*, hard covers, which protect the hind wing and the dorsal part of the abdomen, the *hind wing* is membraneous, study its texture and venation, it folds back on its length the anterior border being jointed for that purpose. The *abdomen* is made up of somites, their terga are soft and dependent on the elytra for protection, there are no external organs of oviposition.

B—THE LARVA. In the last larval stage the body behind the head is soft and distinctly divided into somites, those of the thorax being nearly like those of the abdomen; the head bears a number of distinct *ocelli*, but no compound eyes, the *antennæ* have a basal and one small additional joint. The *mouth parts* are of the biting type. The three *thoracic somites* are wholly free, the anterior bears an enlarged *pronotum*, all bear short *legs* which are five-jointed, the tarsus is undivided and bears a single claw. There are no indications of *wings*. The *abdomen* is nine-somited. Spiracles are located on the *terga* above the distinct *pleural* fold.

All stages from the egg to the last larva can be found on leaves of the potato, the eggs are yellow and attached to the under sides of the leaves, material can either be studied fresh or preserved in alcohol for study when convenient.

6. THE FLY, the body presents the usual regions separated by deep constrictions. The head bears a pair of large, strongly convex many-facetted compound eyes, three small, black, shiny, simple eyes, a pair of short, plumose antennæ, and pecular mouth parts, viz: elongate and sharpened mandibles and maxillæ, enclosed in an elongate tubular labium, closed above with an elongate labrum, they are adapted for piercing and sucking and their action can readily be observed in the case of the musquito. There is no separate pro-thorax, the three pairs of legs are equal, and sub-divided as usual, the tip being furnished with a soft, sucker-like pad, by means of which the fly adheres to walls, etc. There is only one pair of wings, the meta-thoracic being rudimentary (in some represented by knobbed structures called *halteres).* The abdomen is reduced to four somites.

THE EGGS of the flies are laid on putrefying animal or vegetable matter (so that the larvæ on hatching will have a supply of food). They hatch as *maggots*, having a segmented body with circular mouth at one end surrounded by a circle of teeth. After a few days the larva assumes an inactive *pupa* form, a segmented, dark brown, hard coated object, from which after a few days the perfect fly bursts.

7. THE BUTTERFLY. Observations on the living animals are easily made and are valuable; the larval stages or caterpillars can be found on leaves in the garden; if it is kept confined in a cage made by enclosing a box with netting, and fed on food it has been found eating, it will advance into the pupa stage; pupæ are often found out of doors under stones, etc.; they can be kept under observation and the mature insect caught as it emerges. The feeding habits of both the larva and the adult, and the mode of locomotion in both, should be carefully studied.

A—THE ADULT is similar in most families of the order, the head is small and the prothorax reduced, so that the wings seem in the very front of the body; there are two prominent compound eyes, and long, many-jointed antennæ; the mouth-parts are all rudimentary except the maxillæ, which are very long, coiled when at rest, and join to form a hollow tube which is used in sucking nectar from long tubular flowers. Labial palpi are present and conspicuous. The wings are covered with *scales*, minute, regular in shape, inserted by a distinct stem at regular intervals on the surface of the wing; the color and arrangement of these scales, which rub off as "dust," gives the color and marking so characteristic of the butterflies. The limbs are alike, slender and present the usual joints. The abdomen is elongate, it is connected with the thorax by a small junction.

B—THE CATERPILLARS present great differences in color, size and in the shapes and distribution of the hairs which cover their surfaces, but all are fundamentally greatly alike. The body is divisible into a *head* and a segmented posterior part. The head shows an area indicative of the *compound eyes*, but without facets; in this area there are a few *ocelli*, there is a pair of rudimentary *antennæ*, the *mouth parts* are well developed and of the biting order, an upper lip, strong heavy mandibles and a palp-bearing maxilla are recognizable, besides an under lip. There are three thoracic somites directly behind the head, each of which bears a pair of short but distinctly jointed legs; there are no indications of wings. The abdominal somites are distinguishable; the third, fourth, fifth and sixth bear soft non-jointed *pro-legs*, which are not homologous with true arthropod legs, being unjointed and ending in a clamp with a toothed edge used by the larva in walking on the margins of leaves. The terminal segment of the abdomen is also furnished with a pair of similar pro-legs.

C—THE PUPA stages of butterflies differ considerably; still the abdomen can be recognized and outlines indicative of the wings and thoracic legs. The pupa is inert and does not feed. the living insect inside depending on the food taken by the larva. The mature insect, when it first emerges from the larval skin, is soft and its wings much crumpled; they soon straighten and stiffen, and the insect flies away.

8. THE HONEY BEE (adult worker) presents another variation on the Hexapod line; the head thorax and abdomen are separated by deep constrictions, there is no distinct pro-thorax; the head bears antennæ, compound eyes and simple eyes, the mouth parts are: strong, cutting manibles for cutting into a flower, and maxillæ in the form of long, soft lapping structures, the labium bears elongate licking palpi and in the centre an elongate licking tongue, used in collecting honey. The wings are membraneous, few-veined, the hinder is smaller and attached to the front one by a row of microscopic hooks. An ovipositing organ, the sting is located in the tip of the abdomen, it can be seen thrust out in a living specimen if carefully handled by means of a pair of forceps. Besides bees, ants and wasps belong to this order and in spite of great apparent difference present close morphological similarity.

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CHAPTER XIII.—SYNOPSIS OF THE ANIMAL KINGDOM.

NOTE.—This key is based on the writings of Hatscheck, Lankester, Claus, Leunis, Packard, and others; it is only intended to serve as a guide for the adult forms of the more common and larger groups.

PHYLUM 1, PROTOZOA: body unicellular, microscopic, aquatic or parasitic, reproduction asexual—

1. C. RHIZOPODA: free, outline indefinite, skeleton often present,
    1. O. LOBOSA, fresh-water, pseudopodia blunt, skeleton wanting;
    2. O. HELIOZOA, fresh-water, pseudopodia slender unbranched, skeleton radial, siliceous;
    3. O. FORAMINIFERA, marine, pseudopodia branched, skeleton calcareous, often coiled;
    4. O. RADIOLARIA, marine, pseudopodia unbranched, skeleton radial, siliceous.
2. C. INFUSORIA: free or attached, outline definite, no skeleton, an external cuticle,
    1. O. FLAGELLATA, very minute (usually), cilia minute or none, one or more flagella;
    2. O. CILIATA, cilia numerous, some often large and strong;
    3. O. ACINETARIA, no cilia or flagella, with knobbed suctorial tentacular processes.
3. C. SPOROZOA: parasitic, cuticular, outline permanent, no motile processes.

METAZOA: multicellular animals, with asexual and true sexual reproduction;

A RADIALIA: aquatic, with complete or partial radial symmetry.

PHYLUM 2, COELENTERATA: parts not in 5's, tentacles present, body two-layered, no separate body cavity, colonial, marine (exc. Hydra), thread cells present—

1. C. HYDROZOA: no gullet, stomach simple, colony often polymorphic, germ-cells ectodermal,
    1. O. HYDROMEDUSAE, colony sessile, medusae usually becoming free, polymorphism slight (or none),
        1. S.O. TUBULARIAE, hydrozooid not protected by hydrotheca;
        2. S.O. CAMPANULARIAE, hydrozooid protected by hydrotheca.
    2. O. SIPHONOPHORA, colony free, medusae attached, polymorphism considerable.
2. C. SCYPHOZOA: ectodermal gullet, stomach subdivided, germ-cells endodermal,
    1. S.C. SCYPHOMEDUSAE, free, large, larva polypoid, adult medusoid, 4-merous, not colonial;
    2. S.C. ACTINOZOA, attached, polypoid, often colonial, stomach septate, coral forming,
        1. O. RUGOSA, 4-merous, calcareous, (extinct since Palaeozoic time);
        2. O. ALCYONARIA, septa and tentacles 8, tentacles compound;
        3. O. ZOANTHARIA, 6-merous, tentacles simple, often forming coral.
3. C. CTENOPHORA*: body free, gelatinous, 8 rows of ciliated paddles, stomach complex, mouth and vent both present.

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*The Ctenophores are less closely related than Hydrozoa and Scyphozoa. Still it is more convenient to place them with the coelenterates than to make them a separate phylum.

PHYLUM 3, PORIFERA: marine and fresh-water, radial symmetry obscure, body attached, no tentacles, digestive cavities separated by mesoderm space from outer wall, body wall pierced by many openings, skeleton if present internal.

PHYLUM 4, ECHINODERMA: 5-merous, radial and often somewhat bilateral, body 3-layered, body cavity distinct, skeleton generally present, of lime, often spiny, marine—

1. C. CRINOIDEA: brachiate, attached (exc. Comatula) arms many branched, abyssmal, mostly extinct.
2. C. ASTEROIDEA: brachiate, free, star shaped, tube feet only on oral side, skeleton of movable pieces,
    1. S.C. OPHIUROIDEA, arms slender, distinct from disk, no ambulacral groove, no vent, (arms branching in Astrophytidae);
    2. S.C. ASTERIDEA, arms blunt (rarely more than 5), ambulacral groove present, disk not distinct from arms.
3. C. ECHINOIDEA: globular, oblate depressed, free, skeleton of immovable parts, shell external, spiny,
    1. O. CIDARIDEA, radial symmetry prominent, mouth and vent central, ambulacral rows complete;
    2. O. CLYPEASTRIDEA, bilateral symmetry faint, mouth central, vent median, excentric, ambulacra only at aboral pole;
    3. O. SPATANGIDEA, bilateral symmetry prominent, mouth and vent median, excentric, 4 bilateral rows of functional aboral ambulacra.
4. C. HOLOTHUROIDEA: free, globular, prolate, often depressed, leathery, mouth and vent terminal, contractile oral tentacles, 5 ambulacral rows.

B. BILATERALIA: body multicellular, often attaining large size, reproduction most commonly only sexual, symmetry distinctly bilateral.

PHYLUM 5, SCOLECIDA: generally aquatic or parasitic, body not segmented, or, if so, specialized into regions, no lateral appendages, no shell—

1. C. PLATYHELMINTHES: flat, elongate, digestive tube simple or wanting, aproctous. sexes united,
    1. O. TURBELLARIA, free, locomotion by cilia, mouth ventral, no hooks or suckers, aquatic;
    2. O. TERMATODA, parasitic, oral and ventral suckers, sense organs degenerate;
    3. O. CESTODA, parasitic, segmented, segments alike, no mouth or digestive organs, suckers and hooks present.
2. C. NEMATHELMINTHES: cylindrical, filiform, no cilia, cuticularized, sexes separate,
    - O. NEMATODA, digestive system complete—complex, motion by muscles of body wall, parasitic.
3. C. ROTIFERA: free, minute, aquatic, with ciliated fleshy lobes about the mouth.

PHYLUM 6, MOLLUSCOIDA: attached, not segmented, enclosed in shell, tentacles or arms aquatic—

1. C. BRYOZOA: zooid small, colonial, encrusting or branching, skeleton (often) of lime, crown of ciliated tentacles.
2. C. BRACHIOPODA: marine, large, solitary, bivalve, shells dorso-ventral and bilateral.

PHYLUM 7, MOLLUSCA: free, not segmented, no locomotor skeleton, shell often present, foot ventral.

1. C. LAMELLIBRANCHIA: aquatic, foot laterally compressed, acephalous, bivalve right and left shell, hinge dorsal,
   1. O. ASIPHONIA, pallial line simple, mantle without elongate siphons;
   2. O. SIPHONIATA, pallial line sinuate, mantle edges fused and elongated, with siphons.
2. C. GASTEROPODA: foot depressed, head distinct, shell univalve spiral (or wanting), tentacles destitute of suckers,
   1. O. OPISTHOBRANCHIA, shell light, often wanting, not beaked, gills if present behind heart, marine;
   2. O. PROSOBRANCHIA, shell heavy, often beaked and rough, gills in front of heart, aquatic;
   3. O. PULMONATA, shell light and smooth or internal, respiration by lungs in front of heart, often terrestrial.
3. C. PTEROPODA: foot rudimentary, its sides developed as ciliated wing-like fins head indistinct, shell thin or absent [conical, pelagic.
4. C. CEPHALOPODA: foot a siphon, head distinct, oral tentacles present bearing suckers, marine,
   1. O. TETRABRANCHIA, gills 4, tentacles numerous, siphon split, shell many chambered, pelagic, (mostly extinct);
   2. O. DIBRANCHIA, gills 2, tentacles 8 or 10, siphon complete, littoral.

PHYLUM 9, ANNULATA: evident metamerism, regions obscure or distinct, typically with more than 2 pairs of lateral appendages.

1 SUB-PHYLUM ANNELIDA: body vermiform, metameres not bearing jointed limbs—

1. C. CHAETOPODA: metameres bearing evident setae, metamerism obvious,
   1. O. POLYCHAETA, setae numerous, borne on parapodia, body free (S.O. Errantia) or tubicolous (S.O. Tubicolae);
   2. O. OLIGOCHAETA, setae few, not borne on parapodia.
2. C. GEPHYREA: metamerism obscure, no setae (degenerate Chaetopods), marine.
3. C. HIRUDINEA: metamerism obscure, few or no setae, suckers present, externally parasitic.

2 SUB-PHYLUM ARTHROPODA: body complex, regions distinct, some metameres bearing jointed appendages—

1. C. CRUSTACEA: 2 pairs of antennae, respiration branchial or dermal, aquatic,
   1. S.C. COPEPODA, free, minute, antennae locomotor, eyes simple median, no gills, tail forked, or degenerate parasites;
   2. S.C. OSTRACODA, free, minute, antennae locomotor, eyes simple median, bivalve shell;
   3. S.C. CIRRHIPEDEA, attached, degenerate, antennae and eyes aborted, appendages cirrhi, no gills, bivalve shells, marine.
   4. S.C. PHYLLOPODA, free, eyes simple and compound, limbs leaf-like and bearing gills, heart tubular,
      1. O. BRANCHIOPODA, 10—40 pairs of swimming limbs;
      2. O. CLADOCERA, 4—6 pairs of swimming limbs.
   5. S.C. MALACOSTRACA, somites definite, 20 pairs of appendages (counting eyes), antennae sensory, eyes compound,

1. SUP. O. ARTHROSTRACA, eyes sessile, 7 pairs of pereiopods, 1 pair maxillipeds, no branchiostegite, thorax not fused,
    1. O. AMPHIPODA, body compressed, aquatic;
    2. O. ISOPODA, body depressed, (second antennae sometimes wanting,) aquatic and terrestrial;
2. SUP. O. THORACOSTRACA, eyes stalked, thoracic somites (usually) fused and covered by a carapace,
    1. O. STOMATOPODA, gills abdominal, last 3 thoracic somites free, eyes and antennae on free somites;
    2. O. SCHIZOPODA, gills thoracic, pereiopods 7 pairs biramous in adult, 1 pair maxillipeds;
    3. O. DECAPODA, gills thoracic, pereiopods 5 pairs uniramous in adult, 3 pairs maxillipeds,
        1. S.O. MACROURA, abdomen well developed (soft and degenerate in Family Paguridae);
        2. S.O. BRACHYURA, abdomen rudimentary (especially in male sex).

2. C. ARACHNIDA: no antennae, several simple no compound eyes, no gills, no abdominal limbs, 4 pairs pereiopods, 2
[pairs mouth parts, terrestrial,

1. O. SCORPIONIDEA, body elongate, abdomen of 7, post abdomen of 6 somites and terminal sting, second pair of
[limbs chelate, respiration pulmonary, terrestrial (Limulus and the
[extinct Trilobites and Eurhypterida are probably related here);
2. O. PSEUDOSCORPIONIDEA, small, scorpionoid, abdomen short, no post-abdomen, chelate, respiration tracheal;
3. O. SOLIPUGIDEA, head and 3 jointed thorax distinct, long segmented abdomen, no chelae, respiration tracheal;
4. O. PEDIPALPI, cephalothorax and abdomen equal, junction broad. pereiopods long and slender, anterior
5. O. PHALANGIDEA, like Pedipalpi except anterior pereiopod, which is locomotor; [antenniform;
6. O. ARANEIDA, cephalothorax and abdomen equal, junction constricted, 8 simple eyes, abdomen with spinnerets;
7. O. ACARINA, cephalothorax and abdomen fused, degenerate parasites, respiration tracheal;
8. O. PYCNOGONIDA, body small, abdomen rudimentary, limbs large, marine.

The orders Pentastomoda and Tardigrada are very degenerate wholly parasitic Arachnids.

3. C. INSECTA: 1 pair of antennae, eyes simple and compound, sessile, respiration tracheal, terrestrial,

1. S. C. ONYCHOPHORA, vermiform, no distinct head, 2 simple lateral eyes, numerous short, imperfectly jointed
[limbs.
2. S. C. MYRIAPODA, vermiform, head distinct, eyes not strictly compound, remainder not separated into regions,
1. O. CHILOPODA, body flat, limbs 1 pair to each somite; [limbs on all the somites,
2. O. CHILOGNATHA, body cylindrical, limbs 2 pairs in most somites.
3. S. C. HEXAPODA, three distinct body regions, thorax 3 segmented, bearing 6 legs and four wings, (exc. Diptera
[and wingless forms).

Series 1. Ametabola, metamorphosis incomplete.

1. O. THYSANURA, wingless, small, regions indistinct, eyes few facetted, setiform caudal springing filaments;
2. O. DERMAPTERA, body flat, abdomen chelate, anterior wings short and hard covers, rare and nocturnal;
3. O. ORTHOPTERA, pronotum free large, jaws biting, anterior wing hardened, hind wing folded lengthwise or
[rudimentary;
4. O. PLATYPTERA, body flattened, pronotum large and square often wingless, free (Corrodentia) or parasitic,
[(Mallophaga);

5. O. ODONATA, prothorax small, abdomen long cylindrical, junction broad, wings equal and similar, many vein[ed. larva and pupa aquatic;
6. O. PLECTOPTERA, mouth parts rudimentary, abdomen tipped with 3 long filaments, hinder wings small, not [veined, larvae aquatic;
7. O. THYSANOPTERA, small, prothorax free moderate, wings narrow, veinless, fringed, mouth a short conical [beak;
8. O. HEMIPTERA, prothorax large, fore wing often thickened at base, jaws lancet like in tubular jointed beak,
    1. S.O. PEDICULINAE, parasites, suctorial mouth, no wings, thorax not segmented;
    2. S.O. HOMOPTERA, free, wings oblique wholly membraneous, or wanting (in parasites), often hoppers;
    3. S.O. HETEROPTERA, free, prothorax large, wing horizontal, hard at base.

Series 2. Metabola, metamorphosis complete.

9. O. NEUROPTERA, mouth biting, prothorax large, wings equal, not veined, not folded or hooked;
10. O. MECAPTERA, prothorax small, abdomen large and slender, wings equal, not veined or folded;
11. O. TRICHOPTERA, mouth parts obsolete, prothorax small, body and wings hairy or scaly, larvae aquatic, [builds case;
12. O. COLEOPTERA, prothorax free large, mouth biting, fore wing hard, hind wing folded crossways;
13. O. SIPHONOPTERA, wingless, no compound eyes, body much compressed, mouth suctorial, parasites;
14. O. DIPTERA, prothorax fused, mouth piercing and sucking, hind wing wanting, fore wing membraneous;
15. O. LEPIDOPTERA, prothorax fused, mouth suctorial, four very large unfolded usually scaly wings;
16. O. HYMENOPTERA, prothorax fused, mouth licking and biting, wings membraneous, hinder smaller, few [nerved, not folded.

PHYLUM 9, VERTEBRATA: body bilateral, body cavity distinct, metamerism indistinct or wanting, brain [and dorsal spinal cord, limbs 4 or less—

1. C. TUNICATA: degenerate saccular bodies, respiration by gill slits, a notochord in some embryos, marine.
2. C. PISCES: scaly, paired and unpaired fins, respiration solely branchial, heart simple, aquatic,
    1. O. LEPTOCARDIA, degenerate (?) vertebrates, no paired limbs, no shell, heart tubular, no bones, marine, rare;
    2. O. CYCLOSTOMI, paired fins wanting, skeleton cartilaginous, body vermiform, mouth circular, suctorial;
    3. O. SELACHII, paired fins present, skeleton cartilaginous, jaws with teeth transverse, skin naked, marine;
    4. O. GANOIDEI, paired fins present, bony, skin covered with bony plates, or enameled scales;
    5. O. TELEOSTEI, paired fins present, scales large thin and horny, operculum for gills.
3. C. AMPHIBIA: naked, limb digitate, circulation incompletely double, respiration pulmonary in adult,
    1. O. URODELA, tail persistent in adult, gills sometimes persistent;
    2. O. ANOURA, tail falling away, gills never persisting.

4. C. **REPTILIA:** scaly, limbs digitate or absent, tail large, no hair or feathers, respiration solely pulmonary,
    1. O. SAURII, body elongate, tail generally large, limbs anterior and posterior, movable eye lids, tympanic cavity open;
    2. O. CHELONIA, body broad depressed, ribs meeting to form carapace, 4 limbs, no teeth;
    3. O. OPHIDIA, body elongate, serpent form, no outward break between trunk and tail, bifid protusible tongue, no limbs;
    4. O. PTEROSAURIA, wholly extinct aerial reptiles, wing membraneous on one elongate digit;
    5. O. HYDROSAURIA, aquatic, large reptiles mostly extinct, represented today by crocodile and gavial.
5. C. AVES: feathered, tail bones short, anterior limb a wing, no teeth, heart 4 chambered, oviparous,
    1. S.C. CARINATAE, sternum provided with a keel, wing and tail feathers well developed,
        1. O. PSITTACI, beak short stout hooked, tongue large mobile, 4 toed, toes level, 1 and 4 permanently reversed;
        2. O. CUCULI, beak large, tongue small flat, toes level, 4, one either versatile or reversed;
        3. O. PICI, tongue extensile, barbed, beak strong, feet with strong claws, firm tail;
        4. O. CYPSELI, wing very long, humerus very short;
        5. O. PASSERES, bill horny, not cered, small, vocal apparatus well developed, toes 4, reversed;
        6. O. RAPTORES, bill hooked, voice poor, bill membraneous at base, toes clawed, toes 4, 4th toe versatile, carnivorous;
        7. O. COLUMBINAE, bill soft, base membraneous, not hooked, toes 4, 3 in front;
        8. O. GALLINACEI, wing short round, strong beak, flight feeble, legs strong short, largely terrestrial, often spurred;
        9. O. GRALLAE, long thin neck and long beak, elongate wading legs, toes sometimes semi-palmate, partly aquatic;
        10. O. LAMELLIROSTRES, bill long broad lamellate, foot webbed, toes level, hind limb short, well back, aquatic;
        11. O. STEGANOPODES, large swimming birds, toti-palmate, leg posterior, bill not lamellate, wings strong;
        12. O. LONGIPENNES, legs near center, bill not lamellate, wings very long, foot not tolipalmate;
        13. O. PYGOPODES, wings short, feeble flyer, leg posterior, body erect, feet palmate, aquatic;
        14. O. SPHENISCI, wing rudimentary, flight impossible, leg posterior, body erect, foot palmate, aquatic;
    2. S.C. RATITAE, sternum destitute of a keel,
        1. O. CURSORES, wing rudimentary, legs strong, wholly terrestrial.
6. C. MAMMALIA: haired, teeth present, viviparous,
    1. S.C. APLACENTALIA, no placenta, marsupial pouch and bones present;
        1. O. MONOTREMATA, jaws beak-like, feet clawed, cloaca present, oviparous;
        2. O. MARSUPIALIA, jaws not beak-like, viviparous, young very immature.
    2. S.C. PLACENTALIA, placental mammals, no marsupial bones or pouch.
        1. O. EDENTATA, limbs clawed, dentition incomplete, teeth rootless grinders;
        2. O. CETACEA, no hair, front limb a flipper, no evident hind limb, aquatic;
        3. O. PERRISSODACTYLA, herbivorous, hoof single, middle digits excessively developed;
        4. O. ARTIODOCTYLA, herbivorous, hoof cloven, 2 middle digits developed,
            1. S.O. RUMINANTIA, horned, upper incisors absent, chew the cud, stomach complex;
            2. S.O. PACHYDERMATA, hornless, dentition complete, stomach simple, non-ruminating.

5. O. PROBOSCIDEA, very large, molar teeth compound, canine teeth in form of tusks, with trunk;
6. O. RODENTIA, small, digits 4 or 5, clawed, incisor sharp chisel like, canines absent;
7. O. INSECTIVORA, small, fossorial; dentition complete, teeth sharp pointed, insectivorous;
8. O. CARNIVORA, canine teeth well developed, teeth sectorial, well developed claws, carnivorous;
9. O. PINNIPEDIA, haired, aquatic carnivora, limbs digitate, terrestrial only in breeding;
10. O. CHIROPTERA, flying mammals, wing membraneous, bones of front limb much lengthened;
11. O. PROSIMIA, aboreal, foot and hand prehensile, orbit open;
12. O. PITHECI, aboreal, hand prehensile and often feet, nails flat, orbit closed;
13. O. PRIMATES, foot not prehensile, attitude erect.

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